BIOGAS TECHNOLOGY

an information package

TATA ENERGY DOCUMENTATION AND INFORMATION CENTRE
TATA ENERGY RESEARCH INSTITUTE
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INTRODUCTION

Biogas Technology: An Information Package is a revised and updated edition of 'Biogas Handbook' and other biogas information products published during 1981-82.

The present information package is the result of extensive documentation research and networking activities in the area of biogas technology. It provides packaged information on the technology, its development, socioeconomic and political aspects of its diffusion and utilisation. In addition, a survey of biogas programmes in various countries and a selective guide to the documentary and non-documentary information sources have been included. The information package in its present form is intended to be a reference volume that may be useful not only to the biogas professionals but also to those who are concerned with alternate energy options for the developing countries.

A complimentary copy of this publication is being mailed to all the participants of our bioenergy information network. They are welcome to write to us, if necessary, for additional information and documentation on any aspects of biogas technology. We would also welcome them to share their experience in the diffusion and utilisation of biogas technology as an approriate energy option.

N.K. Gopalakrishnan

Tata Energy Documentation and Information Centre

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CHAPTER - 1

AN OVERVIEW

Biogas technology refers to the production of a combustible gas (called biogas) and a value-added fertilizer (called sludge) by the anaerobic fermentation of organic materials under certain controlled conditions of temperature, pH, C/N ratio, etc.

1.1 Historical Perspective

Biogas production is a natural phenomenon When plant and animal matter are decayed in the absence of air, the action of certain bacteria produces an inflammable gas. This gas came to be called biogas, gobar gas, marsh gas, etc. However, recognition of the potential of this phenomenon and its subsequent practical application were initiated only recently.

Since the 1920s, there have been sporadic attempts made to recover biogas from sewage wastes and animal dung. A few biogas plants for sewage disposal and biogas recovery were installed in Europe and the U.S.A. in 1920s and 1930s respectively. China had its first biogas plant in 1936. In India, an experimental biogas plant was installed in 1946; by the early 1950s India had developed a viable plant design for biogas production from cowdung.

A spurt in biogas-related activities was observed during the 1970s when two basic plant designs were developed and field tested - the Indian model with a floating gasholder and the Chinese one with a fixed dome. Besides accelerating biogas production in these countries, this led to the spread of the technology to several other Asian countries as well.

However, animal dung was considered to be the principal if not the only input material for biogas production during this period. India was using cowdung for biogas production whereas China, the Philippines, Thailand etc., were using piggery wastes. The plants were mostly family - size units attached to rural households. Consequently the use of biogas had been limited principally to the rural domestic sector. Also, the fertilizer potential of the sludge was not recognized fully during the period. However, a number of plant models and biogas stoves and lamps were designed and developed in countries like China, India, Nepal, etc. Research efforts to isolate and identify the micro-organisms and understand the specific types of reactions taking place were initiated towards the end of the 1970s.

1.2 Current Status

Biogas technology is becoming increasingly popular among the developing and developed nations alike. In many of the African and Latin American countries, for instance, it is being pursued as an appropriate rural technology for energy and fertilizer production. The advanced nations, on the other hand, are turning to the technology for pollution control and large-scale energy production. With over 8.5 million biogas plants already operational in China and India, the technology is currently being promoted in over 45 countries with widely varying agro-climatic and physico-geographic conditions.

China and India are in the forefront of the development and promotion of the technology. Nearly 90% of the 8.5 million plants currently in operation are installed in China alone. Current Chinese programmes for biogas development aim at intensifying the R&D programmes and streamlining the diffusion campaigns to ensure proper communication between R&D personnel and extension workers. Next to China, India has the largest biogas development programmes. Biogas plants in India account for about 3.5% of the total number of plants in operation today.

Besides family plants, India has initiated programmes for community plants and already 31 such plants have been commissioned.

As regards the other Asian countries, Taiwan, the Republic of Korea, Thailand, etc., have made some headway in the adoption of the technology.

Biogas plants in these countries are mostly small-scale family plants. Thailand, however, is exploring the potential of large-scale plants using food processing wastes and farmyard manure as feedstock. Meanwhile, countries like Fiji, Indonesia, Malayasia, Pakistan, the Philippines, Sri Lanka, etc., are in the process of assessing the feasibility and establishing the credibility of the technology in their rural areas. For this purpose, several demonstration plants have been set up in these countries, and they seem to generate interest among the villagers. For instance, the demonstration programmes in Pakistan have generated the demand for as many as 15,000 plants. In the case of the Philippines, nearly 500 family-size plants have already been installed.

The national priorities for biogas development in Africa vary from fuel and fertilizer production to public health and environmental improvement. Countries like Botswana, Ethiopia, Kenya, etc., are currently involved in modifying the available know-how to suit their agro-climatic and feedstock conditions. Tanzania, on the other hand, has developed a plant model to suit her farmers and demonstration programmes. In the case of Egypt, a well-conceived demonstration programme has been drawn up, under which a few plant units of Indian and Chinese designs have been installed.

Brazil and Guatemala are the two central places for biogas development in Latin America. Brazil launched her National Biogas Programme in 1978 and currently approximately 50,000 plants are in operation. In Guatemala, a project on the reutilization of bio-degradable wastes was initiated in 1977 and several Chinese and Indian model plants have been installed. As regard the rest of the Latin America and Caribbean nations, biogas demonstration programmes are in the offing. To illustrate, countries like Peru, Bolivia, Guyana, Hondures, Jamaica, Mexico, etc. are in the process of setting up demonstration plants. The models being sponsored are indigenously developed designs. Examples are Guatemala-OLADE model, Xochically-Mexico model, CETA model, IIE model, etc.

1.3 Potential

The potential of biogas technology is in the simultaneous generation of fuel, fertilizer and feed from the same organic material. In addition to these immediate benefits, the technology can be instrumental in organic waste recycling, sanitational improvement, environmental management and pollution control, if properly exploited. However, in actual practice, the priority attached and the benefits accrued from the technology would depend on the specific level of the beneficiary concerned. For instance, the national priority for adopting the technology may not be the same as that of an individual beneficiary. Similarly the benefits accrued at the national and individual levels may not coincide with each other. For convenience, some of the benefits from the viewpoints of the individual, community and national level beneficiaries are shown below:

i) Individual level

Immediate: Clean and efficient cooking fuel; Better lighting.

Long-term: Improved health by eliminating smoking fuels; Improved sanitation especially if the toilet is attached to the plant;

Chances of leisure (by saving time spent for collecting firewood and making cowdung cakes).

ii) Community level

Immediate: Possible source of power for small-scale agro-industries;

Growth in agricultural productivity (by using sludge as fertilizer);

Animal feed from waste.

Long-term: Reducing pollution from animal and human waste;
Improved chances of employment;
Better chances of indigenous development.

iii) National level

Long-term: Savings in foreign currency spent on kerosene and chemical fertilizers;
Reducing the need for expensive distribution of energy in rural areas;
Minimising environmental pollution;
Supplementing forest conservation measures.

1.4 Economic Implications

Notwithstanding the aforementioned benefits, biogas technology can have a negative impact on the rural plant owners of the third world. The most important among these is that biogas technology demands a certain degree of financial commitment and a particular pattern of lifestyle from them. To illustrate, the capital cost of a biogas plant, the high initial capital investment on its installation as well as the periodical maintenance/repair costs would be in most rural contexts, beyond the means of an average farmer. This is further aggravated by the fact that the plant does not result in any direct or immediate cash benefit to them. On the contrary, the technology might be making farmers pay for the fuel and fertilizer which were available free earlier.

Secondly, ensuring a steady supply of biogas for any one type of domestic fuel need also pose problems in certain cases. A steady gas supply can be guaranteed only if the plant owner is capable of maintaining a certain number of cattlehead. Experience in several developing countries has shown fluctuations in the cattle wealth of farmers due to reasons of drought, adverse economic conditions during the lean period, high mortality rate of livestock, etc.
Seasonal variations in temperature further slow down the pace of biogas production unless the plants have been adequately protected. Further, the incidence of system close-down for cleaning and/or repair also interrupts gas supply for cooking or lighting.

In general, the mass appeal and large-scale adoption of a technology in a specific context need not necessarily be directly proportional to its technical feasibility and simplicity of operation. Often, certain seemingly minor points (for instance the non-availability of water for slurry preparation) can be seen to hinder the progress of technology in a village. Added to this is the likely resistance of the villagers to change, which is born out of certain social and religious practices and habits.

1.5 Future Prospects

In spite of the above problems, the interest in the technology is on the increase. The reasons are basically two. The first is the impetus it gets from the concerned national governments and international organisations. The other factor is the ability of the technology to adjust to the demands of specific microlevel applications. As regards the former, promotion efforts are being initiated in view of the technology's capacity for energy production, waste recycling, sanitational improvements, etc. Many of the developing countries are offering liberal financial assistance for plant installation, maintenance, purchase of plant parts and construction materials,large-scale production of plant parts and devices like stoves, lamps, etc. Financial assistance would go a long way in the popularisation of the technology. This is besides research and diffusion efforts in the country. Provision is being made in several countries for developing all the required infrastructural facilities like construction of plants, extension training, setting up of small-scale industries for the production of equipments as well as for the use of the biogas generated.

As regards the capability of the technology for adjustment, several of the barriers to its promotion are being identified and rectified. Now the farmers falling short of cattleheads can make use of agricultural wastes and even plant wastes like weeds for biogas production. Moreover, community plants where several households can pool in their resources is also becoming a viable proposition in such contexts. A number of plant models to reduce the cost of construction and maintenance have recently been designed. Integrated systems which ensure the economic and efficient use of the products would also gather momentum in due course. This flexibility of technology together with promotional efforts from the national governments would positively render biogas plants appropriate and viable for a rural environment.

CHAPTER - 2

PRINCIPLES OF BIOGAS PRODUCTION

Biogas is generated by the anaerobic fermentation of various organic materials like livestock wastes, agricultural crop residues, industrial processing wastes, etc. During the last few years, there have been substantial research efforts to understand the microbiology and chemistry of biogas production. The process of anaerobic fermentation invovles a series of biochemical reactions. The specific nature and type of some of these reactions are yet to be understood. As regards developments in the microbiology of biogas production, several strains of bacteria contributing to these reactions have recently been isolated and identified.

2.1 Chemical Process

The series of complex reactions involved in the digestion of organic wastes to biogas can be broadly divided into two main phases: an acidogenic phase in which the organic wastes are converted mainly to acetate and the methanogenic phase in which methane and carbon dioxide are formed.

2.1.1 Acidogenic Phase

Acid phase fermentation is a key step in biogas production, since it results in the generation of acetate which is the primary substrate for methane formation. The terminal end-products of acid-phase fermentation are acetate, higher fatty acids, CO_2 and H_2. The formation of these products is mediated by a complicated network of enzymatic reaction chains. The polymeric carbohydrates contained in the complex organic wastes are hydrolysed by enzymes to simple soluble sugars and short-chain organic acids like acetic acid, propionic acid, lactic acid, etc., and methanol, ethanol, propanol, etc. (The celluloses and starches of the complex organic wastes are hydrolysed to simple sugars while proteins are hydrolysed to amino-acids. Fatty acids are the only compounds that are not acted upon by the extra-cellular enzymes).

The primary breakdown of sugars in fermentation is to pyrivic acid, with liberation of hydrogen in the form of a hydrogen-carrier complex. This hydrogen could then be used to reduce pyruvic acid to propionic acid. Pyruvic acid can also be reduced to ethanol by a different pathway:

$$C_3H_4O_3 + 2H \longrightarrow C_2H_6O + CO_2$$

or to lactic acid:

$$C_3H_4O_3 + 2H \longrightarrow C_3H_6O_3$$

Pyruvic acid can also be converted to butyric acid (via acetic acid derivatives):

$$2C_3H_4O_3 \longrightarrow C_4H_8O_2 + 2CO_2$$

or converted to succinic acid (via propionic acid):

$$C_3H_4O_3 + CO_2 + 2H \longrightarrow C_4H_6O_4 + H_2O$$

The production of acetic acid from pyruvic acid is:

$$C_3H_4O_3 + H_2O \longrightarrow C_2H_4O_2 + H_2 + CO_2$$

The hydrogen can then be used by the methanogenic bacteria to form methane and water:

$$4H_2 + CO_2 \dashrightarrow CH_4 + 2H_2O$$

2.1.2 Methane Phase

This involves the conversion of the intermediary products of the acid phase to form methane. The main substrates for methanogenesis are acetic acid and hydrogen plus carbon dioxide. Acetic acid is usually regarded as the most important substrate.

The overall reactions occurring in the second phase of anaerobic fermentation are known; but complete details of the biochemical mechanisms involved are yet to be brought to light. The overall reactions involved in the production of methane can be due to the cleavage and reduction respectively of acetic acid and hydrogen. The cleavage of acetic acid results in the conversion of methyl carbon to methane and carbon dioxide. Carbon dioxide is further reduced to methane.

$$2C_2H_4O_2 \dashrightarrow 2CH_4 + 2CO_2$$
$$4H_2 + CO_2 \dashrightarrow CH_4 + 2H_2O$$

If the methanogenic bacteria are growing with the sugar-fermenting bacteria the removal of hydrogen will induce the bacteria to form more hydrogen, thus instead of a mixture of acetic and propionic acids:

$$C_6H_{12}O_6 \dashrightarrow C_2H_4O_2 + C_3H_6O_2 + CO_2 + H_2$$

acetic acid would be produced:

$$C_6H_{12}O_6 + 2H_2 \dashrightarrow 2C_2H_4O_2 + 2\,CO_2 + 4H_2$$

The hydrogen formed in the initial split of glucose to pyruvic acid would be released as hydrogen gas and more hydrogen would be released in the formation of acetic acid. The $4H_2$ would then be combined with CO_2 to form methane. In a similar way the production of ethanol, lactic acid and the other reactions shown above, would be displaced in favour of acetic acid and hydrogen production.

In the formation of methane from carbohydrate 66% of the methane is estimated to have come from acetic acid while 33% is from hydrogen.

2.2 Microbiological Process

Effective digestion of organic wastes into methane requires the combined and coördinated metabolism of different kinds of carbon catabolizing anaerobic bacteria. At least four different trophic types of bacteria have been isolated which can be distinctly recognised on the basis of substrates fermented and metabolic end-products formed. The different types of bacteria identified are:

a) ***The hydrolytic bacteria*** which ferment a variety of complex organic molecules (i.e. polysaccharides, lipids and protein) into a broad spectrum of endprodcuts (i.e. acetic acid, H_2,CO_2, one-carbon compounds, and organic acids larger than acetic acid, neutral compounds larger than methanol);

b) The hydrogen producing ***acetogenic bacteria*** which include both obligate and facultative species that can convert organic acids larger than acetic acid (e.g. butyrate, propionate) and neutral compounds larger than methanol (e.g. ethanol, propanol) to hydrogen and acetate;

c) The ***homoacetogenic bacteria*** which can ferment a very wide spectrum of multi-or one-carbon compounds to acetic acid; and

d) The ***methanogenic bacteria*** which ferment H_2, CO_2, one-carbon compounds (i.e. methanol, CO, methylamine) and acetate into methane. The methanogenic bacteria perform a pivotal role in anaerobic digestion because their unique metabolism controls the rate of organic degradation and directs the flow of carbon and electrons by removing toxic intermediary metabolics and by increasing the thermodynamic efficiency of interspecies intermediary metabolism (i.e. those of the other stages).

Methanogens are a very morphologically and macro-molecularly (i.e. cell wall, lipid and DNA-GC composition) diverse bacteria having a unique property to produce methane in the absence of oxygen. So far the following genera of methanogenic bacteria have been identified: (i) Methanococcus, (ii) Methanobacterium, (iii) Methanosarcina, (iv) Methanospirillium, and (v) Methanobacilus. All the known species of methanogens can use hydrogen and produce methane. Table 1 gives morphological and growth characteristics, of some methanogens.

Table 1 Methanogenic Bacteria : Morphology and Growth Characteristics

	Organism	Morphology	Optimum Temps.	Dimension Length (m)	pH Optima	Electron Donor (Energy Source)	Sulfur Source
1.	Methanobacterium formicium	Rods, single pairs or chains	37-45	2-15	6.6. - 7.8	Hydrogen and formate	Cysteine
2.	M. Strain MOH	- do -	37-39	2-4	6.9 - 7.2	Hydrogen	Cysteine or H_2S
3.	M. arborphilicum	- do -	37-39	2-3.5	7.5 - 8.0	Hydrogen	Cysteine or H_2S
4.	M. Strain AZ	- do -	- do -	2-3	6.8 - 7.2	- do -	Cysteine
5.	Methanosarcina barkeri	Sarcina	35-40	1.5-5.0	7.0 (6.7-7.2)	Methanol and Hydrogen	-
6.	Methanobacterium ruminantium	Coccus chains	37-39	1-2	6.0 - 8.0	Hydrogen and formate	H_2S
7.	Methanococcus vanniellic	Coccus	36-40	0.5-4.0 (diameter)	7.4 - 9.2	Formate	-
8.	Methanobacterium mobile	Rod	40	-	6.1 - 6.9	Hydrogen or formate	-
9.	Methanobacterium thermoautotrophicum	Rod	65-70	5-10	7.2 - 7.6	Hydrogen	H_2S
10.	Methanospirrilum hungatic	Spiral rods	30-40	50	6.8 - 7.5	Hydrogen or formate	-

CHAPTER - 3

FERMENTATION PARAMETERS

Anaerobic fermentation is being governed by a number of parameters like temperature, pH, C/N, etc.

3.1 Airtightness

Microorganisms can be either facultative or obligate. Facultative anaerobes are capable of shifting from a metabolism that uses free oxygen to one that does not. Several of the hydrolytic and acetogenic bacteria are facultative ones. However, the methanogens are strictly obligate and hence can survive only in the absence of free oxygen. As a result, the digester for biogas production has to be made airtight.

3.2 Temperature

The temperature for fermentation will greatly affect the rate of biogas production. There are two ranges of temperatures over which the anaerobic bacteria grow: mesophilic range of 21-45°C and the thermophilic range of 55-70°C. Most of the anaerobes have an optimum activity at 35°C-40°C. However, certain strains of thermophilic methangens like M. ***thermoacetotrophicum*** and ***methanothermus*** have recently been identified. They grow between 63°C-97°C. Further, the bacteria are found to be highly sensitive to temperature fluctuations. For instance, sudden changes in temperature exceeding 3°C is found to affect the microorganisms adversely.

One disadvantage of thermophilic digestion is that the biogas generated will have more H_2S content in it. This increased H_2S production would give biogas an offensive smell, which might create problems in the use of biogas for certain purposes.

3.3 pH

The anaerobic micro-organisms require a neutral environment for optimum functioning. The hydrolytic and acetogenic bacteria can survive in as low a pH as 5.5; however the optimum pH for the methanogens is between 6.8 to 8.5. However, the slurry in the digester usually has a buffer system to balance the pH level. During start-up of a biogas plant the new slurry which has not developed the buffer system can be helped by the addition of chemicals or by the addition of sludge from plants already in operation.

3.4 C/N Ratio

Both the acid-forming and methane forming bacteria require a C/N ratio ranging from 25-30 for optimum functioning. However, the various organic wastes used for biogas production differ unduly in their C/N ratio and hence an optimum mix of the input materials is necessary to get the optimum C/N of 30.

A C/N balance line can be used to balance the C/Ns of two different input materials. The line is marked off like a ruler, with the C/Ns of the input materials used. The proper ratio of the weights of the input materials can be decided as follows:

$Ca - Ct = Da$

$Ct - Cb = Db$

$\underline{Da} = Wb$

Db

where Ca = C/N of substrate A

Cb = C/N of substrate B

Ct = The target C/N

Da = Distance Ca must go to get C_t

Db = Distance Cb must go to get C_t

Wb = weight ratio of substrate B needed to balance 1 unit of substrate A

However Wb gives only the weight ratio of the substrate B. In order to find out the dry weights of these substrates the weight ratio of the substrate is to be multiplied by its C + N number, i.e.

(Da) (Cn(n)a) = DWa

(Wb) (Cn(n)b) = DWb

where

CN(n)a = the C+N number of substrate A

CN(n)b = the C+N number of substrate B

DWa = Dry weight of substrate A

DWb = Dry weight of substrate B

DWa and DWb when multiplied by their respective H_2O numbers would give the wet weight of the input material.

In order to determine the amounts required for more than two substrates, the same process has to be gone through more than once. Obviously one cannot produce a target C/N of 30 if the C/N ratios of both the input materials are below 30. However, while selecting a mixture of organic wastes as input, care must be taken to select those whose combined C/N ratio is closer to the optimum of 25-30.

3.5 Solid Content

The organic wastes, during anaerobic digestion, are decomposed into their constitutent elements like carbon, oxygen, hydrogen, nitrogen, etc. The quantity and quality of biogas generated from an organic waste is decided by its total solids content, volatile and fixed solids.

The weight of the organic material left after an hour of drying, or the weight that is unchanged after several drying is called its dry weight, dry matter or Total Solids (TS). Total solids comprise of Total Volatile Solids and Ash. Volatile Solids (VS) represent the organic matter present and hence are available for biological decomposition. The volatile solids are constituted by the carbon, nitrogen, hydrogen, oxygen, etc. and are determined by burning the material at 600°C when elements like C, O, N, N etc. get evaporated. The left-over ashes or the Fixed Solids are inorganic and hence not available for biological decomposition.

However, VS is not a very accurate measure of the material biologically available to the micro-organisms. This is because the lignin content of the organic waste gives a high percentage of VS, and lignin hardly contributes to biogas production.

VS and FS are generally given as percentage of TS to dry weight.

C+N number is the approximate reciprocal of the percentage of C+N in each substrate, multiplied by 100, or 100 (%C + %N)

H_2O number is the approximate reciprocal of percentage TS multiplied by 100; or 100 %TS.

3.6 Water Content

The optimum water content of the input material would be about 90% of the weight of the total contents. If the water content is too high, the rate of biogas production per unit volume in the digester will fall, whereas with too little water content acetic acid accumulates, inhibiting the fermentation process.

However, studies on the role of water in anaerobic fermentation at the New York State College of Agriculture and Life Sciences of the Cornell University, U.S.A., have shown that relatively dry mixtures of organic materials would be efficiently converted to methane when fermented. It was found that both the rate and efficiency of anaerobic fermentation was relatively unaffected at a moisture level as low as 68% of the total weight. (Decreasing the water content from 68 to 60% of the total weight resulted in the accumulation of volatile acids and the inhibition of biogas production). This process of using input materials of less water content (up to 68% of the total weight) is called dry fermentation and appears to simplify the process and enhance the possibilities of using agricultural crop residues for biogas production.

3.7 Toxic Substances

High concentration of ammonia, antibiotics, pesticides, detergents, heavy metals like chromium, copper, nickel, zinc, etc., are toxic to the microorganisms involved in biogas production. A low C/N ratio of the slurry leads to a high concentration of ammonia. Antibiotics used in animal feed or injected into the animals can cause difficulties in biogas production in plants using manure as the input. Heavy metals are mostly present in industrial wastes.

The maximum allowable concentration of some of the harmful materials is given below:

Sulphate (SO_4-)	5,000 mg/litre
Sodium chloride (NaCl)	40,000 mg/litre
Copper (Cu)	100 mg/litre
Chromium (Cr)	200 mg/litre
Nickel (Ni)	200-500 mg/litre
Cyanide (CN)	below 25 mg/litre
ABS (detergent compound)	40 part per million
Ammonia (NH_3)	3,000 mg/litre
Sodium (Na)	5,500 mg/litre
Potassium (K)	4,500 mg/litre
Calcium (Ca)	4,500 mg/litre
Magnesium (Mg)	1,500 mg/litre

3.8 Hydraulic Retention Time (HRT)

HRT is the average number of days a unit volume of slurry stays in the digester. Under optimum conditions, 80-90% of the total biogas production is obtained within a period of 3-4 weeks. Hence for small-scale, semi-continuous plants, the HRT will generally be 30 days or more. HRT is in fact a design parameter and can be changed acording to the size of the plant, temperature of fermentation, washout time, etc. If the HRT is too low, the bacteria are washed out of the digester as fast as they can multiply, resulting as an unstable bacterial population. The lower limit of HRT is the washout time or the time required for the methanogenic bacteria to replenish their numbers at a certain temperature.

The upper limit is a question of economics of plant construction.

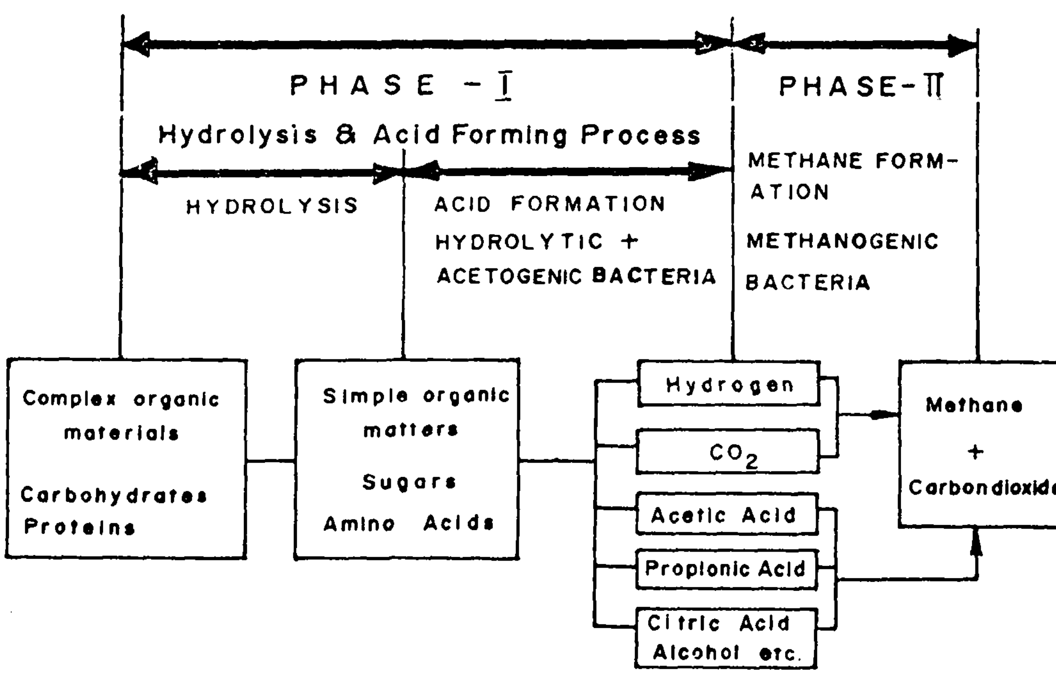
3.9 Organic Loading Rate

Loading rate is the weight of volatile solids loaded each day on the digester, divided by the volume of the digester. Loading rate is an important parameter especially in continous-fed plants, since a high loading rate may affect the pH of the slurry. Even though the volatile solids fed into the plant are converted to volatile acids by acidogens the pH is affected if the rate of action of methanogens on the volatile acids is not compatible with its rate of production.

3.10 Diphasic Digestion

The above parameters become critical in the case of conventional anaerobic fermentation system where both the acid and methane production stages take place in the same physical unit. This is because different strains of physiologically and micromolecularly different bacteria operate in the same unit. Consequently there is likely to be insufficient growth of anaerobes and the subsequent washout.

Diphasic digestion in which the acid and methane production stages are separated, has been found to be effective in providing the optimum parameters for the respective bacteria. Separation of the phases is effected by controlling the hydraulic retention time since the minimum generation time of facultative microbes is found to be shorter than that of the obligate microbes.



DIPHASIC DIGESTION

CHAPTER - 4

INPUT MATERIALS

Any organic material is a potential input for biogas production. The commonly used materials are wastes like animal and human manure, agricultural crop residues, aquatic plants, industrial and municipal solid wastes, etc. The characteristics, problems and processing of the waste materials are reported below:

4.1 Livestock Wastes

A variety of animal wastes like cattle manure, piggery waste, poultry manure, dung of goats, elephant, horse, etc., are being used as substrate for biogas production. Cattle manure and piggery waste are the most commonly used ones.

The constitution and biodegradability of the animal manure varies from animal to animal. Some of the properties of livestock wastes which decide their biodegradability and rate of biogas production are shown in chapter 18.

The rate of biogas production also varies from one type of waste to the other. Chief among the parameters deciding the amount of biogas generated from substrate are its VS content, % of VS destruction and the amount of biogas produced per gram of VS destroyed.

However, the above figures have been obtained based on the assumption that 100% of the manure produced by the animal is being used for biogas production. In actual practice the amount of dung produced by each animal itself varies according to the size of the animal, its diet, climatic conditions, etc.

The amount of dung that can be made available from each animal depends on factors like.

- amount of manure produced per animal:
- teed composition of the animal;
- manner and completeness of collection (dung plus urine and bedding as well. Is all or only some of the manure colected?)
- stabling habits of animals;

4.2 Human Excreta

Human excreta is an important raw material for biogas production. C/N ratio of this raw material ranges from 6-10 and has 74% water in it. Per capita contribution of human excreta per day is estimated to be 200 gms on a wet weight basis from which approximately 0.02-0.03 m^3/day of biogas can be produced.

4.3 Plant Wastes

A wide variety of terrestrial and aquatic plants are recently being studied for their potential in biogas production. Agricultural crop residues like paddy, wheat and barley straw, banana stem and banana skins, grass and leaves, wild growing plants like Lentana camara, Ipomea sps. etc., are some of the terrestrial plant wastes so far tried for the production of biogas. Among the aquatic plants, water hyacinth, algae, African Payal (Salvinia species), duckweed (Lemma triscula), water lettuce (Pistia stratiola), ocean kelp, etc., have shown great potential for biogas production.

The carbon-nitrogen ratio of the substrate which is a crucial parameter for anaerobic fermentation varies widely from one plant waste to another. For instance, the C/N ratio of fresh grass (lawn cuttings) is estimated to be about 19 while that of fresh leaves is 60. Furthermore, variations have been reported in the C/N ratio and percentage of nitrogen in one and the same type of plant waste. Similarly, exact figures as to annual production and availability of wastes, especially of aquatic plant wastes and that of wild-growing terrestrial plants in a region are hardly available.

While using plant wastes for biogas production, the C/N ratio can be brought to the optimum by adding animal manure as starter. Most of the plant wastes will have to be chopped and pretreated before feeding. Pretreating and cutting to uniform size ensures faster fermentation. Due to their light density and tendency to form a scum on top of the standing slurry, plant wastes are best used in batch-fed biogas plants.

4.4 Industrial and Municipal Solid Wastes

Industrial wastes like willow dust, ozonated pulp mill effluent, fruit and vegetable wastes from canning factories, etc., and municipal solid wastes also can be effectively used as inputs for biogas production. The properties of the various industrial wastes, problems in their anaerobic fermentation and the yield of biogas etc., are yet to be studied extensively.

CHAPTER - 5

BIOGAS PLANTS

A biogas plant is the physical installation where biogas is generated. A typical biogas plant consists of a ***digester*** where the anaerobic fermentation takes place, a ***gasholder*** for collecting the biogas, the ***input-output units*** for feeding the influent and storing the effluent respectively and a ***gas distribution system.***

5.1 Basic Designs

A number of specific biogas plant models have recently been developed, based on a few basic designs. The basic plant designs can be classified according to two characteristics: (a) the arrangement of the gasholder in the plant and (b) the mode of flow of the slurry through the plant.

5.1.1 Arrangement of Gasholder.

Depending upon the arrangement used for collecting biogas, the plant designs are of the following categories:

a) Flexible Gasholder Design

The gasholder in this design is a flexible unit attached to the digester. The gasholder may be a drum floating on the slurry supported by a central guide pipe as in the Indian model, or it will be floating between the two walls of the digester containing a water column topped with oil to prevent evaporation.

The movable gasholder helps in maintaining fairly constant gas pressure in the whole gas distribution system, besides facilitating slurry stirring. However, the gasholder in the majority of such models will have to be made of special materials like mild steel, fibre-glass, ferro-cement, etc., the availability, transport and fabrication of which might pose problems in certain situations. Moreover, the gasholder in certain models dips in the slurry and gets corroded easily. This necessitates periodical painting/maintenance of the gasholder. The KVIC or the Indian model is a typical example of this design.

b) Integrated Design

In the integrated design, the digester and gasholder form a single unit and are mostly made of the same material. One significant advantage of this design is that both the digester and the gasholder can be built below the ground thereby saving space and facilitating temperature regulation inside the plant. The cost of construction also tends to be less when compared to the flexible gasholder design.

However this design does not facilitate steady pressure inside the gasholder and the gas distribution system. Plant construction also requires greater care and skill.

The Chinese Fixed Dome model is an integrated design in which an upward extension of the digestor serves as the gasholder. The Flexible Bag design, on the other hand, is a bag-type plant incorporating the digestor, gasholder, and a settling tank.

c) Separate Gasholder Design

The separate gasholder design is mainly intended for large-scale industrial plants eventhough there are attempts to adapt this model for rural small-scale use. In this system, two to four digesters are usually connected to a single separate gasholder. The system has several advantages. It allows a continuous gas supply with batch feeding. The digesters can be built below ground level thereby ensuring a steady temperature. Repairs and maintenance of individual parts are easier than in other models. However, the separate gasholder model necessitates separate stirring devices for individual digesters.

5.1.2. Mode of Slurry Flow

The mode of slurry flow is another significant characteristic to be considered, in the design of biogas plants. Plant designs based on different flow characteristics are as follows:

a) Continuous-fed, High-rate Mixed Design.

Continuous-fed, high-rate mixed design or high-rate design is that which is fed on substrates which mix easily with water (e.g., cattle manure) and require a stirring device, heating system, pumping system for the sludge and plant monitoring system. The size of the plant depends on the HRT decided and the daily load of feed material available. They are generally smaller in size. This design can generally avoid the problem of scum accumulation.

Due to the short retention time of these plants, between 40%-60% of the biogas which it is possible to generate from the slurry is not produced. More over, the plant operates on a tightly knit balance of fermentation conditions like temperature, loading rate, solid contents, etc., and hence the problems associated with maintaining the optimum conditions and plant monitoring.

b) Continuous-fed Intermittently Mixed Design.

Also called Moderate-rate design, it has less sophisticated agitation and pumping system designs and uses less energy and is suited for the homogenous cattle manure slurry. Most of these plants operate on the gravity feed/displacement flow system. These plants are not easily upset by changes in fermentation parameters.

However, the moderate-rate plants tend to be larger in size because of their longer HRT.

c) Plug-flow Design

The slurry in these plants moves from one end of the digester to the other by gravity displacement and has no auxiliary system except for heating. The plug-flow design is simple and suited for farm-size applications.

d) Batch-fed, Mixed or Unmixed Design

In batch fed plants, the substrate is fed in batches at regular intervals. One batch is generally emptied only after fermentation is complete. The design is low-cost, and simple in construction and can operate on any substrate that is being fed. Manual labour is required for the periodical filling and emptying of the plant. Moreover, gas production in the batch-fed plant is irregular.

e) Hybrid Design

A hybrid plant is one where the acid formation stage is separated from the methane formation stage. A large, cold, batch or continuous first stage produces fatty acids for a smaller hot, continuously fed, second stage. This system needs only little heat and further it renders system monitoring easy. However, the hybrid plant may not be economic for small-scale rural applications.

5.2 Optimisation Of Plant Dimensions

Optimising plant dimensions goes a long way in economising plant construction materials, capital cost of plant, installation as well as in reducing the retention time. In spite of these merits attempts for a theoretical approach for detailed dimensioning of plants are few and far between. This is because conventionally, the dimensions of a plant with a specific rated capacity of biogas production per day are given by the agencies/institutions sponsoring the concerned model.

During the last few years, efforts are being undertaken to optimise plant dimensions with a view to reducing capital cost and/or reducing the retention time. Of these, particular mention may be made of a study for the optimisation of floating drum gasholder model plants done in India. The parameters for optimisation and calculation of dimensions in the above study are given below.

5.2.1 Minimisation of Capital Cost

Optimisation based on minimising the capital cost of plants, should consider two principal factors contributing to capital plant cost, i.e., the cost of the gasholder and the cost of the digester. In other words, capital cost R (cap) is given by

R(cap) = R+R' where R is the capital cost of the gasholder and R' is the capital cost of the digester. The capital cost of the gasholder is decided by the following parameters:

V = volume of the gasholder
y = maximum fraction of the daily gas produced which is intended to be stored in the gasholder
C = actual plant capacity
D = diameter
h = height
t = thickness
d = density
u = unit cost in Rs/kg (this includes the cost of steel, transport, fabrication, welding and painting of the gasholder)

The capital cost of the gasholder can be calculated as follows

$$R = (4\ ay\ C/D) + (\pi\ a\ D^2/4)$$

where a = tpu

The capital cost of the digester, on the other hand, is a function of

h' = height of the digester
t' = thickness of the masonary (assuming it to be the same for the base, sides and partition wall of the digester)
u' = unit cost of the masonary (in Rs/unit area)
u_e = unit cost of excavation (in Rs/unit area)

D = diameter of the digester (slightly higher than that of the gasholder in the case of floating gasholder models but assumed, for convenience of calculation, to be the same)
C = actual plant capacity

The capital cost R' of the digester is given by

$$R' = (\pi D^2 \beta\ 4) + (8 \beta \phi C/D) (1 + \frac{1}{\pi}) = 2\ u'_e\ C$$

The total capital cost of the plant (i.e. capital cost of the gasholder plus capital cost of the digester) is given by

$$R(cap) = (4 \delta C/D) + (\pi \epsilon D^2/\ 4\ ) + 2\ u'_e\ C$$

where $\delta = ay + 2\phi\beta(1 + \frac{1}{\pi})$; and

$\epsilon = a + B$
$\beta = t'u'_p$
$\phi = t_d\ p_s l\ Y$
(detention time (td) x density of slurry ($p_s l$) x gas yield/ unit weight of dung Y)

The diameter of the gasholder and that of the gasholder of the plant model to be optimised can be calculated as follows:

$$D'_A = D_A = (8\delta/\pi\epsilon)^{1/3} C^{1/3}$$

The height-to-depth ratio for the

optimised digester pit is

$$h'/D'_A = h'_A/D_A = \phi \epsilon / \delta \; *$$

The optimised dimensions of the digester correspond to that when the total capital cost of the gas-holder and digester is minimised.

The height of the gasholder is determined as follows :

$$h_A = 4yC/\pi D^2_A$$

The total capital cost of the plant (when the capital cost of the digester plus capital cost of the gasholder are minimised) is given by

$$R_A 9cap) = (27\pi\epsilon\delta^2)^{1/3} \; C^{2/3} = 2\,\phi\, u'_e C$$

5.2.2 Reducing Detention Time

Detention time affects the capital and operational costs of a biogas plant. A longer detention time results in greater gas yield from a given amount of volatile solids. However, this necessitates greater digester volume and therefore increases capital cost. A shorter detention time on the other hand, ensures cheap digesters but it has the danger of washout and hence less gas output.

The optimum detention time can be determined by minimising the the sum of the capital and operational costs or by maximising the return from the plant given by the net operational revenue minus the capital cost.

The detention time derived after minimising total capital cost and operating costs might be different from that of conventional plant models. However, further research efforts are required for optimising plant dimensions corresponding to optimised detention times.

5.2.3 Optimised Models

As already mentioned, conscious efforts for optimising plant dimensions for minimum cost and reduced retentions time are largely sporadic in nature. In several of the new plant designs, cost reduction is achieved by resorting to low cost construction materials and not by optimising plant dimensions. Perhaps the only case where cost reduction is affected by optimising plant dimensions and retention time is the ASTRA model.

5.3 Thermal Analysis of Plants

Slurry temperature in the digester has been found to be a critical factor in the rate of biogas yield and the detention time necessary for effective biodegradation of the feed materials. In fact, the reaction rate constant is found to be approximately doubled for every 10° to 15° increase in temperature in the mesphilic range. Further biogas production decreases drastically in locations where ambient temperatures fall below 10°C in winter.

Recognising the importance of slurry temperature in biogas production, countries like India, Nepal FRG, etc., have recently initiated research efforts to increase gas production by providing optimum temperature in the plant. These experiments deal mostly with external plant heating and range from plant insulation with materials like rice husk and rice straw to providing solar water heaters

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* These equations are on the assumption that the unit civil engineering costs of masonary construction and excavation are independent of depth (i.e. $u'_e \neq f(h')$. On this basis, R(cap) is differentiated with respect to D and the result set equal to zero the diameter $D'_A = D_A$ and hence height to diameter ratio corresponding to the minimum total capital cost can be calculated as above.

for the gasholder.

External heating of plants, especially in the floating gasholder models where the gasholder is above ground, is necessitated due mainly to the following :

i) the temperature of the slurry within the digester is not significantly different from the ambient temperature, implying thereby that the rate of internal heat generation from the nominally geothermic reaction is negligible.

ii) there is a tendency for loss of heat from the plant, especially from the sides and roof of the gasholder.

An attempt to predict the thermal balance of biogas plants has been made in India and a simple thermal model has been developed for this purpose. The thermal model helps in estimating the temperatures of some of the components of the biogas plant, i.e., the gasholder, the gas inside the holder and the slurry. The model should consider the total heat inputs and loss in the plant. The parameters to be considered for calculating the heat transfer co-efficients in a plant are as follows :

a) Convective heat transfer
   - from the top of the gasholder to air
   - from the gasholder side surface to the air
   - from the gasholder inner surface to the air
   - from the gasholder portion that is immersed in the slurry to the slurry

b) Radiation heat transfer
   - absorption co-efficient of gasholder for solar radiation.
   - emissivity of gasholder at long wave length.

The energy stored in the gasholder will be based on the solar influx + radiative exchange of the outer surface of the gasholder with the sky and ground (convective heat lost from the outside surface of the gasholder) - (heat lost to the gas inside the gasholder) - (heat lost to the slurry through the portion immersed in the slurry).

The energy conservation in the slurry is a function of parameters like.

- temperature of the gasholder.
- temperature of the slurry
- convective heat transfer coefficient of the gasholder immersed in the slurry
- heat lost from the slurry through the side walls of the digester, etc.

Further, when a plant in which the slurry temperature is maintained at 35°C is fed with a 'cold' fresh slurry (i.e. at an ambient temperature) the heat loss for the slurry has been found to be not negligible.

5.4 Plant Installation

5.4.1. Selection of Model

Selection of a plant model appropriate for a particular agroclimatic condition depends on several variables. For instance, availability of construction materials and skilled manpower required for construction are very important considerations in the selection of a plant model. Similarly the feed material intended to be used is equally significant since it decides the mode of slurry flow in the digester. Climatic conditions and soil characteristics like soil stability are the other important considerations.

5.4.2 Selection of Size

Size of the gasholder is generally a function of the amount of biogas required at a time and the amount of gas produced. Digester size, on the other hand, is decided by the HRT allowable, temperature of the area, quantity of feed materials available etc.

Decision on digester size can be illustrated by the following example 36 litres of biogas is produced when 1kg of cattle dung is digested in 50 days at 27°C slurry temperature; about 28kg of dung will be needed daily to produce $1m^3$ of biogas/day. The volume of the digester will then be $2.8m^3$ (i.e. 28kg + 28kg water multiplied by 50 days HRT, assuming 1kg dung = 1 litre volume).

5.4.3. Selection of Site

A careful selection of the site best suited for the plant must be made, based on the following factors :

a) The site should be close to the supply of input material to save time and effort in carrying it to the plant.

b) Installing plant close to the points of biogas use (e.g. kitchen) would be economic in terms of the gas distribution system.

c) The site should be 10 to 15 metres away from shallow wells in order to prevent contamination.

d) It should be free from any intrusion of trees the roots of which may creep into the digester and cause damage.

e) The location should be in the sun but not in the low lying areas.

f) The location should have suitable foundation conditions.

g) The site intended should have enough space for construction of the plant and pits for storing sludge.

5.4.4. Materials For Construction

Building materials like bricks, cement, concrete, steel, etc., are used for the construction of the digester. In places where rural skills in brick-making, brick-laying, plastering and bamboo-craft are well developed, clay bricks or mortar have been used.

A low-cost neoprene rubber bag and a mixture of red mud, PVC, plasticizer, stabilizer, etc., called Red Mud Plastic are being used for plant construction in Taiwan. The possibility of using PVC, Low Density Polythene (LDPE), fibreglass reinforced plastic etc., for the digester are being studied.

Gasholders are generally made of the same material as digesters, in the case of fixed dome plants. The flexible gasholder models however use mild steel, ferro-cement, etc. Prototype of fibre-glass, High Density Polythene (HDPE) are being developed for the gasholder.

The gas pipes and its accessories are made of galvanised iron or plastic. The inlet and outlet tanks are made of the same material as the digester.

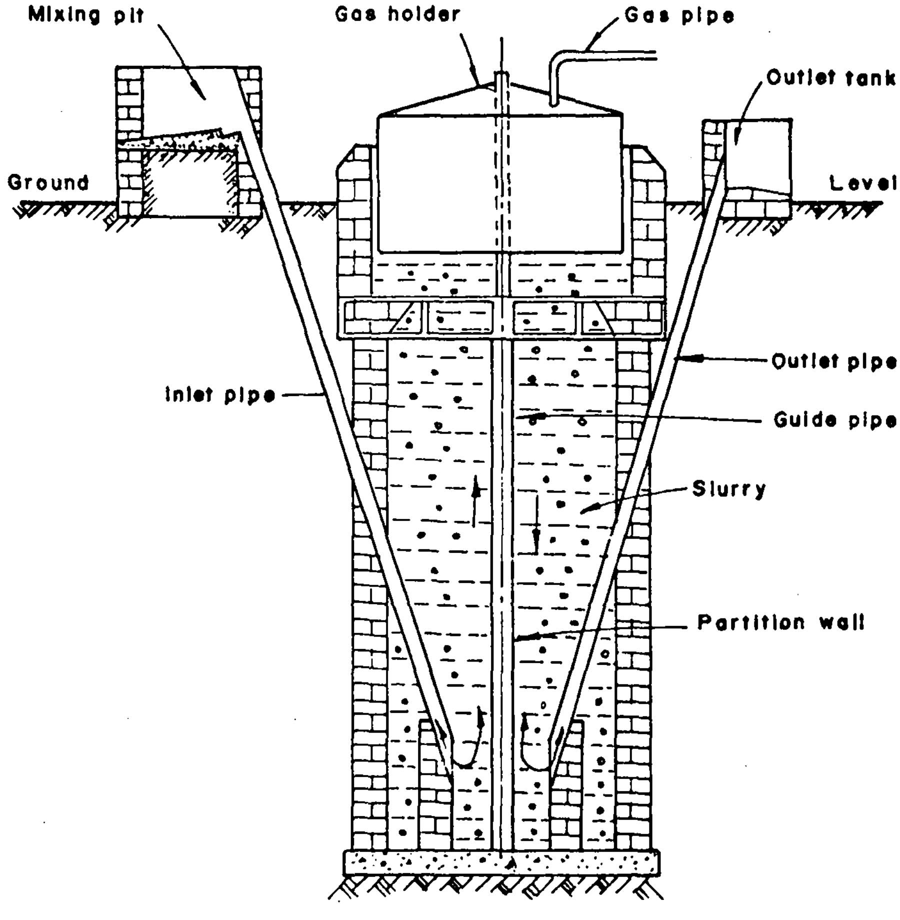
5.5. Performance Evaluation

Control over biogas plant performance can be effected by studying environmental factors like pH, VS concentration, temperature, nutrient availability, concentration of toxic materials etc. of the slurry. Equally significant are operational factors like composition of organic substrate, HRT, organic loading rate, degree of mixing, heating and heat balance, effluent concentration, etc. Efforts at performance evaluation of biogas plants are however sporadic in nature.

CHAPTER - 6

PLANT MODELS FOR PARTICULATE SLURRY

Over the years, a number of biogas plant models incorporating one or the other characteristics mentioned in the preceding discussions have been developed by various institutions/agencies to suit specific local conditions. A few of the representative models have been given below. These are models for particulate slurry. Particulate slurry includes the slurry prepared from input materials like livestock wastes, agricultural crop residues, acquatic plants, etc.



KVIC MODEL

6.1 KVIC Model

The KVIC model has been designed by the Khadi and Villagee Industries Commission, India, based on a model originally designed by J.J. Patel in 1951. The model has now come to be known as the Indian model.

The KVIC model is the pioneer of the floating drum gasholder design. The digester in this model is an underground masonry tank, the depth of which varies according to the size of the plant. The digester of a small plant may be without a partition. However, it is advantageous to have a partition in bigger plants so that the digester may be used as a two-stage one. The gasholder is a balancing tank for continuously receiving the gas produced in the digester and delivering it at a predetermined pressure to points of use, when required. The gasholder also acts as a cover of the digester. It fits like a cap on the mouth of the digester well where it dips in the slurry and rests on a ledge constructed in the well for this purpose.

The drum rises as the gas is collected in it, and in its up-and-down movement, it is guided by a central guide pipe fitted in a frame which is fixed in masonry work. This arrangement allows the gasholder to rotate and break any semi-dried matter formed on the surface of the slurry in the digester.

The inlet and outlet pipes are two slanting cement pipes reaching the bottom of the digester well on either side of the partition wall and have their opening on the surface in the inlet and outlet tanks. The mixing tank mixes feedstock materials and water and also serves as the inlet tank. To lead the gas to the pipe, kitchen or to other usee points within a distance of about 10 m, a galvanized iron pipe of 1.2 cm-1.9 cm diameter is usually used.

The KVIC model is generally run on a continuous basis. After plant construction 10 days time should be allowed for proper curing and plastering of the digester before feeding. During the first loadng, both the compartments of the digester must be filled equally as otherwise the partition wall is likely to collapse due to uneven pressure. Scum breaking is done by rotating the gasholder once or twice every day to break the scum. During winter, measures are to be taken to maintain optimum slurry temperature.

The gasholder of the model requires periodical maintenance. To prevent rusting of the gasholder and prolong its life, it should be painted once a year.

The most important advantage of the KVIC model is its capability to maintain steady pressure of biogas by the movements of the gasholder. The in-built provision for scum breaking is an added attraction.

However, periodical maintenance of the gasholder for preventing corrosion and the difficulties associated with maintaining optimum fermentation conditions especially when the digester is exposed to atmospheric pressure and wind are the chief constraints in the popularity of the plant. Furthemore, mild steel itself tends to be an expensive construction material in many of the developing countries. Transportation and/or on-site fabrication of the gasholder might also pose problems in the context of certain villages.

Despite the above problems, a number of KVIC model plants are being installed in India and several other developing countries.

Efforts are being made to bring down the cost of the plant by optimisation of parameters and substituting mild steel by less expensive materials.

For further information, contact:

The Director,
Gobar Gas Scheme,
Khadi & Village Commission,
3, Irla Road,
Vile Parle (West),
Bombay 400 056
INDIA.

6.2 Chinese Model

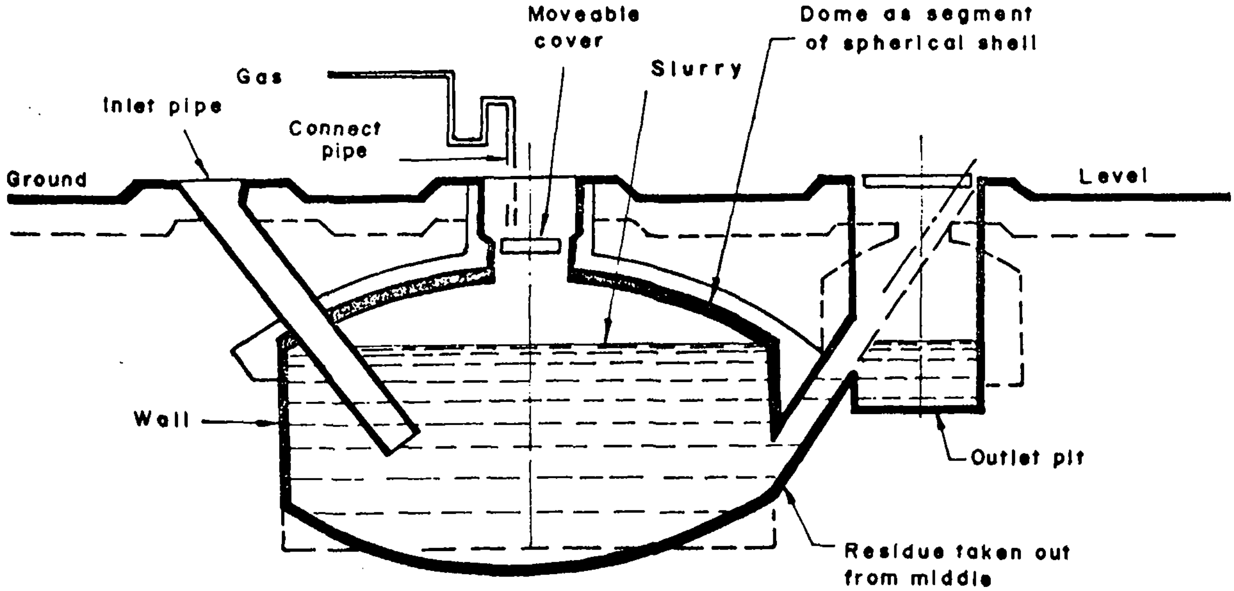
The Chinese Model is the first fixed dome model to be developed.

The present Chinese Model plant is a small circular tank with the digester and the gasholder combined into one unit. The whole plant is built below the ground and uses locally available materials for construction.

An upward extension of the digester into a dome-shaped structure acts as the gasholder. The digester has a separation wall above the mouths of the inlet and outlet in the fermentation tank. Large-size plants incorporate a wooden mixing device for breaking the scum. A manhole fitted at the top, with a removable cover facilitates maintenance and permits removal of sludge while cleaning out the digester.

Materials like lime-clay, lime-concrete, concrete, bricks, stones, etc., can be used for plant construction. Three types of plant structures are commonly used, namely, cast-in-place tank, masonry tank, and tank cut-in-place. Two major approaches to construction are used. In one, the tank is built with minimum displacement of soil which is dug out afterwards from the finished structure. In an alternate approach, the soil is first removed by digging a pit and the unit is constructed in that pit.

The Chinese model plant is a combination of the batch-fed and continuous-fed type and uses a mixture of animal dung, mostly piggery



CHINESE BIOGAS PLANT

waste, and agricultural crop residue as input. The agricultural crop residues are fed in batches while the animal dung is added daily.

Except for preventing gas leakage and water leakage, the Chinese model plant does not require major maintenance/repair work. However, the contents of the plant are to be emptied and the digester cleaned periodically, say once a year or so.

Owing to the use of locally available construction materials, the construction cost of the Chinese model plant tends to be low. Being completely underground, there is a considerable saving in the space required for plant installation. Furthermore, underground construction facilitates maintaining optimum slurry temperature within the digester.

However, construction of the dome-shaped gasholder requires highly skilled manpower. In addition, the fixed dome plant does not allow automatic regulation of pressure of biogas.

The Chinese model plant is very popular in China. Several other countries have also adopted the design with or without modifications.

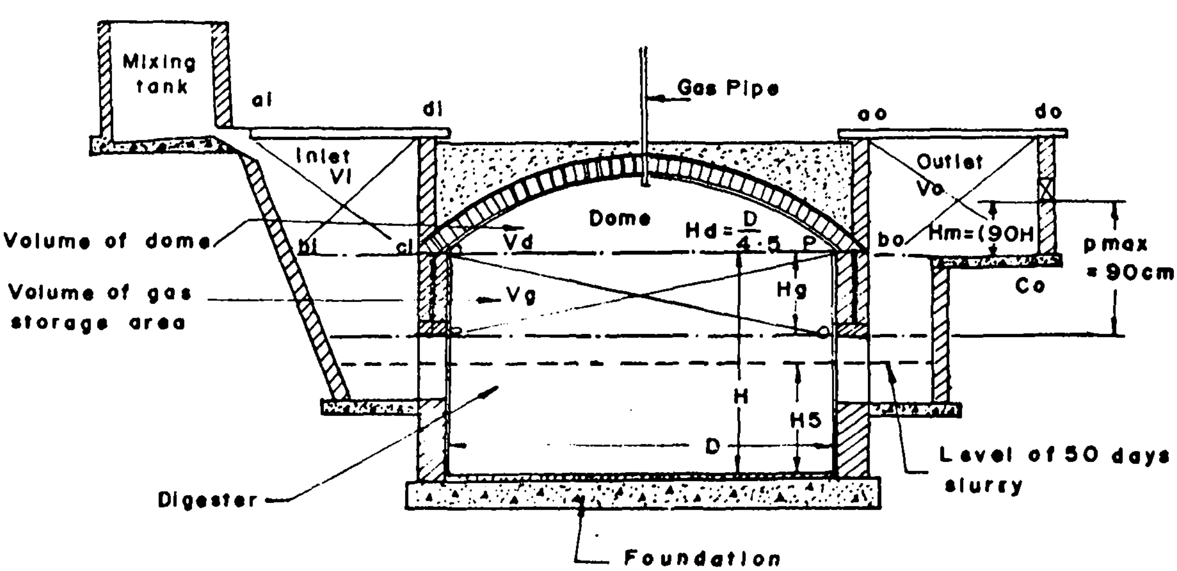
For further information, contact:

Szechuan Provincial Office of Biogas Development,
Chengdu,
Szechuan,
PEOPLE'S REPUBLIC OF CHINA.

6.3 Janata Model

Currently one of the popular biogas plant models in India, the Janata model was designed by the Uttar Pradesh State Planning Research Institute, Gobar Gas Research Station, Ajitmal, India in 1977. The Janata Model is a modification of the Chinese Fixed Dome Model.

It is a continous fed one with an underground cylindrical digester and a hemispherical dome without man-hole cover (closed dome). The gas outlet is through a small piece of GI pipe fitted at the top of the dome. The heights of the opening of the inlet and outlet pipes from the floor of the digester are the same. An opening is provided in the outer wall of the outlet chamber for discharging the sludge.



JANATA MODEL BIO-GAS PLANT

The construction materials being used are chiefly bricks, cement and concrete. The digester and the gasholder dome are made of bricks and cement masonry. The floor of the digester is of cement concrete and brick ballast. The dome is constructed with 'foam work' prepared from locally available shuttering materials such as wooden planks, bamboo, etc. The digester walls and the floor of the digester are to be cured for four days and the dome for six to eight days.

The cost of construction of the Janata model is low since locally available materials can be used for construction. Moreover, the model does not generally require periodical maintenance. Being underground, the slurry temperature can be kept fairly steady.

The model, however, requires great care and skill for construction. Especially the construction of the dome should receive utmost care. Agitation of the slurry for breaking the scum is also generally difficult.

However, the Janata model is becoming increasingly popular in India. Attempts are being made to further improve the model by bringing down installation cost and increasing gas production efficiency.

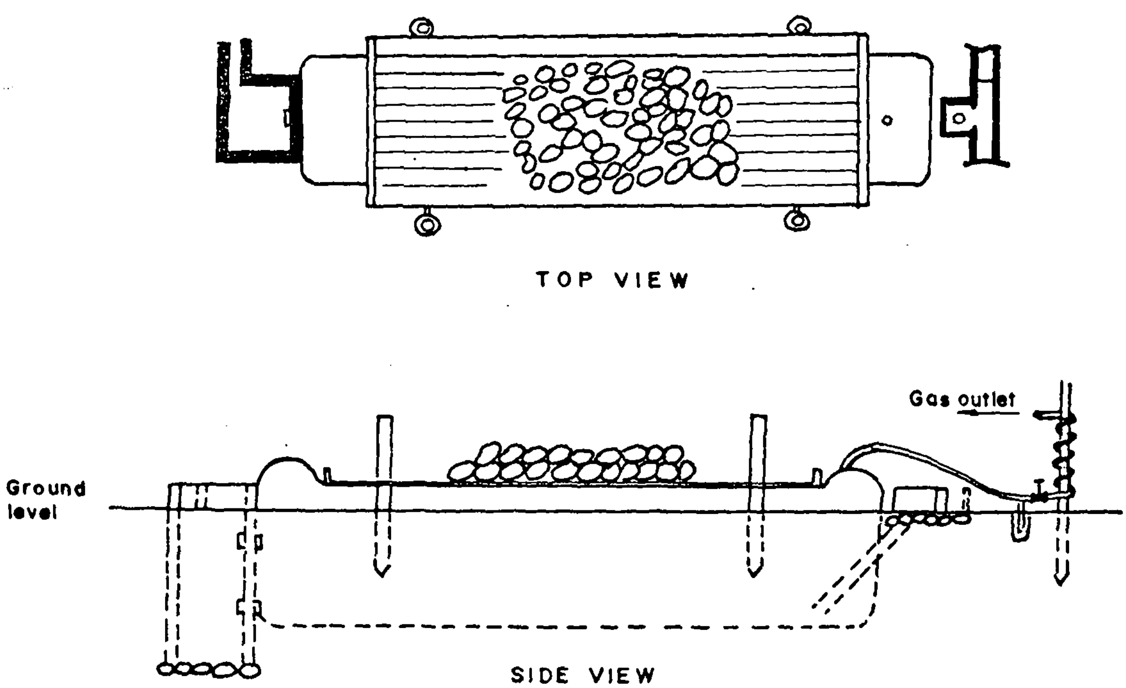
For further information, contact:

U.P. State Planning Institute,
Planning Research & Action Div.,
Kalakankar Bhavan,
Lucknow,
INDIA.

6.4 RMP Model

Developed by the Union Industrial Research Laboratories, Taiwan, the RMP model is a variation of the flexible bag type design.

The construction material used is a mixture of red mud, PVC, plasticizer, stabiliser and other ingredients. A cavity is to be dug on the ground according to the intended size of the digester. Since the RMP is a flexible grade plastic, the size of the cavity



RMP MODEL

should be slightly bigger than the digester body when in use. On the bottom of the cavity, the inlet area is to be slightly higher than the outlet area so that the digester can be washed out easily. The inflated RMP bag after checking for leaks is laid in the cavity. A safety jar and a T-tube are connected to PVC gas outlet pipe. The safety jar is full of water and is buried upto its neck in the ground.

When gas bubbles are seen in the safety jar, the gas is ready to be used. Gas pressure can be regulated by keying a big flat piece of plywood stabilised by steel or wooden poles and putting a few heavy stones on top of the plywood. Scum formed during fermentation settles to the bottom of the tank.

The plant is to be emptied out and cleaned once a year.

The RMP model is also easy to manufacture, install and also for transportation. Repair and maintenance of the plant is also easy.

The model is currently being used in Taiwan and several other countries.

For further information, contact:

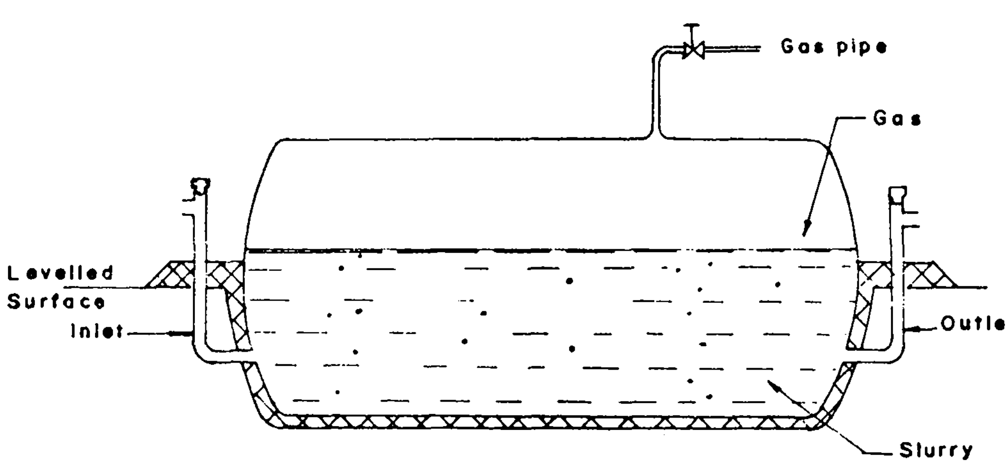
Dr. Tsu-Fu Wang,
Head of Development Dept.,
Union Industrial Research Laboratories,
Industrial Technology Research Institute,
1021 Kuang Fu Road,
Ksiuchu, Taiwan,
REPUBLIC OF CHINA.

6.5 Neoprene Model

Developed by Dr. Chung Po of Taiwan, the neoprene bag type plant is one in which both the digester setting tank and the gasholder are combined into one unit.

The plant is a cylindrical neoprene rubber bag approximately 3.3 m long and 1.5 m in diameter with an inlet and outlet pipe. The biogas produced gets collected in the bag above the slurry level and is piped out by many PVC tubings fixed to the bag.

The prefabricated neoprene rubber bag is to be kept in a hole dug for the purpose. The hole should be carefully cleaned of all sharp stones, tree roots, glass or any other objects which could damage



Neoprene Bag Model

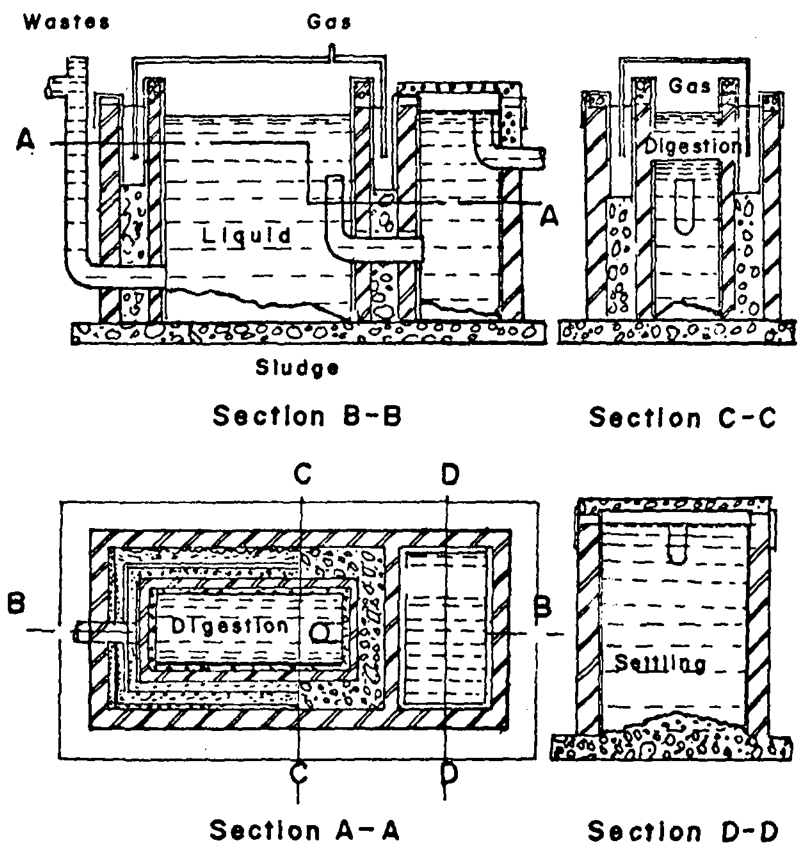
the rubber bag. When the hole for the bag is complete, a trench about 22.5 cm wide to depth of within 30 cm from the bottom of the hole should be extended for a further 30 cm from the centre of each side. While preparing the biogas bag, particular attention is required to support the outlet and inlet PVC pipes so that the rubber is not pinched against the rigid PVC pipes or metal bands over these pipes. The bag should be inflated with air to check for leaks prior to installation. Leaks if found, must be repaired immediately. The biogas bag needs to be supported upto the level of the liquid slurry inside the bag and this is done by placing the bag in a hole dug upto this level. The outlet of the bag has to be in level with the ground.

Presently, the plant is being used as a continous-fed one run mainly on piggery waste. A T-trap connected to the gas line acts as the water trap-pressure device.

Maintenance of plant is mostly in relation to detecting and repairing leaks in the bag. Inlet and outlet pipes must be protected against the run-off from heavy rain storms.

The most significant advantage of the model is that the neoprene bag can be prefabricated and transported easily to any remote area. The plant is easy and simple for installation.

However, the plant is to be made of strong plastic materials resistant to ultraviolet rays.



A 300-GALLON CONCRETE AND STEEL DIGESTER

The model is currently being propagated at the Institute of Natural Resources, University of South Pacific, Suva, Fiji.

For further inforamtion, contact:

Dr. Chung Po,
37, Nan Hai Road,
Taiwan,
TAIWAN (ROC).

6.6 Taiwanese Model

The Taiwanese model biogas plant is based on the principle of Integrated Biogas System in which the sludge is used for production of algae and as animal feed.

The model is a variation of the flexible gasholder design. The digester consists of a digestion chamber which is double-walled, and a settling chamber. The steel gasholder floats between the two walls that contain water topped with oil to prevent evaporation.

Costruction of the plant is generally easy. There should be a screen at the inlet to prevent grass and leaves from entering the digester.

The slurry enters the inner chamber of the double-walled digestion chamber. The water seal in the digester prevents the gas from escaping until the gasholder rises high enough to break the water seal. The gasholder drops down again until equilibrium is re-established. The effluent from the digester is subsequently oxidised in shallow basins for producing algae and in deeper ponds for producing fish. The mineralised effluent is then used in vegetable gardens. If the levels are well set, the whole system will work on the overflow principle, and one operation-i.e. washing the animal house twice a day - will load the digester to produce biogas, grow algae, feed the fish and check ponds and irrigate and fertilize crops.

The model is being used mostly in Taiwan:

For further information, contact:

Mr. George L. Chen,
P.O. Box 151, CHRB,
Saipan, Mariana Islands,
CM 96950,
U.S.A.

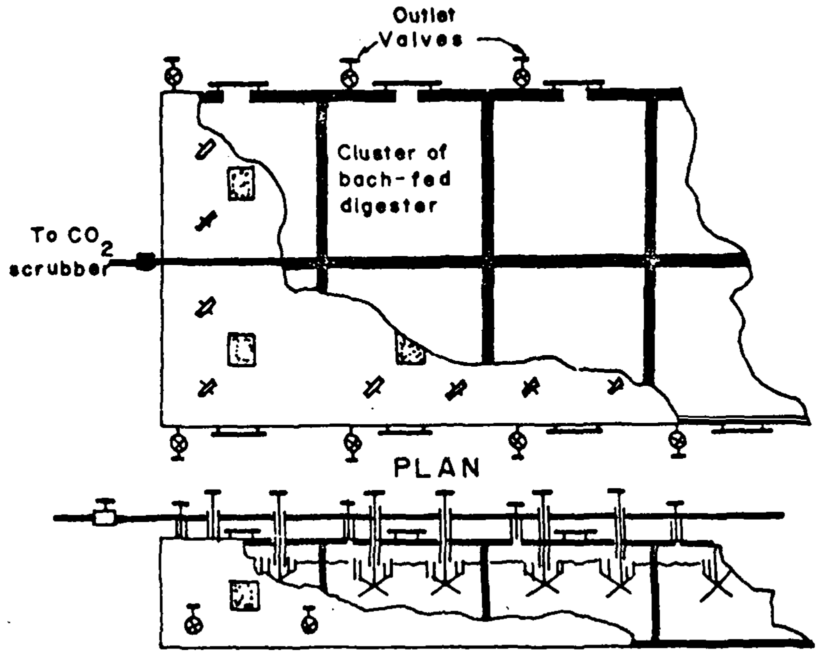
6.7 Maya Farms Model

The Maya Farms Model has been designed by Mr.F.D. Maramba, Sr., Maya Farms Division of Liberty Flour Mills, Philippines. The model is basically of separate gasholder design modified to suit large scale application.

The model consists of a cluster of digesters as many in number as the number of days of retention time plus one. The capacity of each digester is equal to the quantity of daily available slurry and starter. The gasholder is an inverted cylindrical steel tank separate from the digester and floating over water in an open concrete tank. The sludge conditioning unit consists of settling basins, precipitation canals and sludge conditioning lagoons.

The digesters are above ground constructed in such a way that side walls are shared by adjacent digesters. The digesters are all sealed in order to make the operation hygenic and non-polluting.

Piggery wastes constitute the chief input material for the plant. The multiple digesters ensure steady gas production rate. The sludge from the plant goes first to the settling basins where the solids are retained by grass cutting provided at the end of the basin while the liquid flows out to the precipation canal. The finer solids get precipitated as the liquid flows through



BATCH-FED DIGESTER FOR AGRO-INDUSTRIAL OPERATIONS
(Maya farms—Maramba)

the canal to the conditioning lagoons. The conditioned liquid serves as fertiliser-irrigation water for crop fields and fish ponds while the solids are used as animal feed.

For further information, contact:

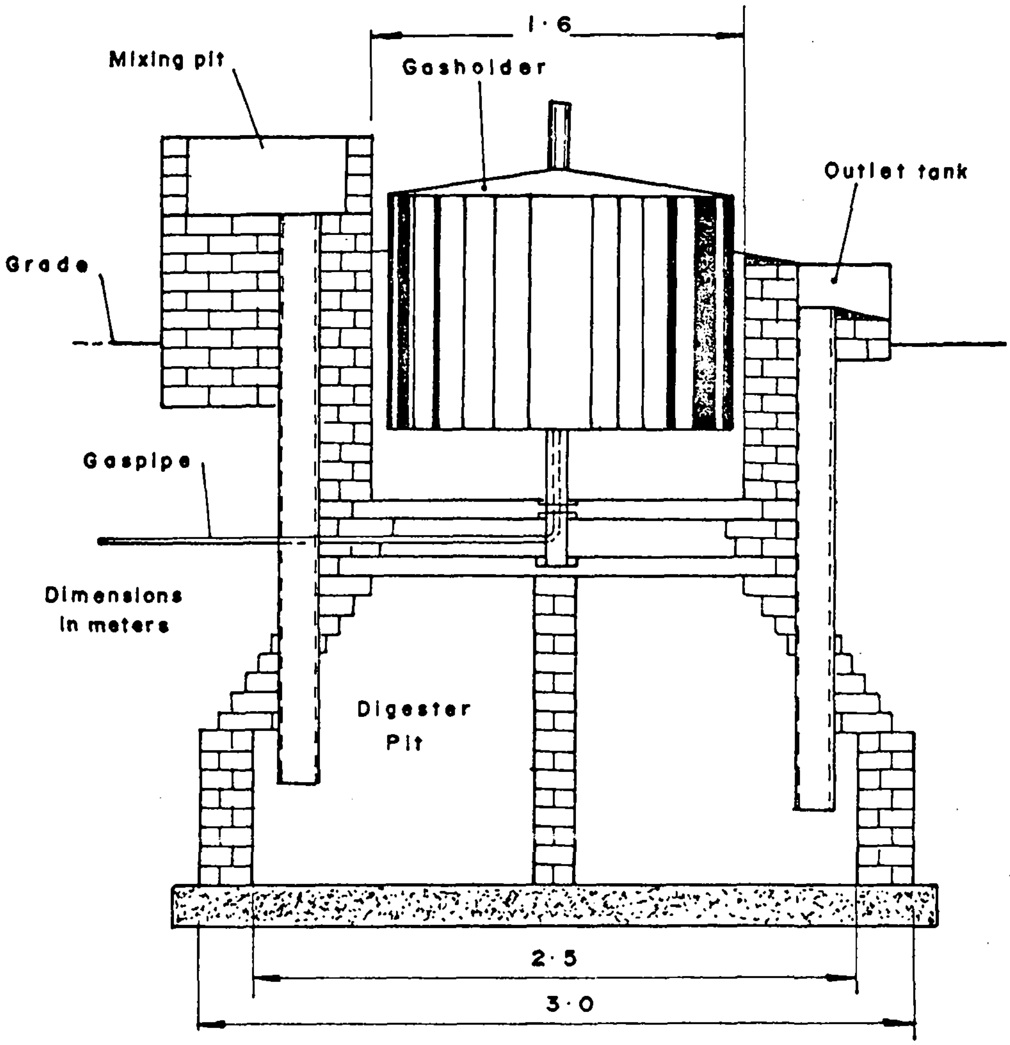
Dr. Felix D. Maramba,
Maya Farms Div.,
Liberty Flour Mills, Inc.,
Liberty Building,
Pasay Road, Makati,
MM PHILIPPINES.

6.8 DCS, Nepal Model

This is a modification of the flexible gasholder design in which the biogas produced is piped through an underground fixed pipe attached to the central guide pipe rather than through the flexible hose at the roof of the gasholder. Both straight design and tapering design suited for high and low water table areas respectively, are available.

For further information, contact:

Mr. D.J. Fulford,
Development and Consulting Services,
Butwal,
NEPAL.



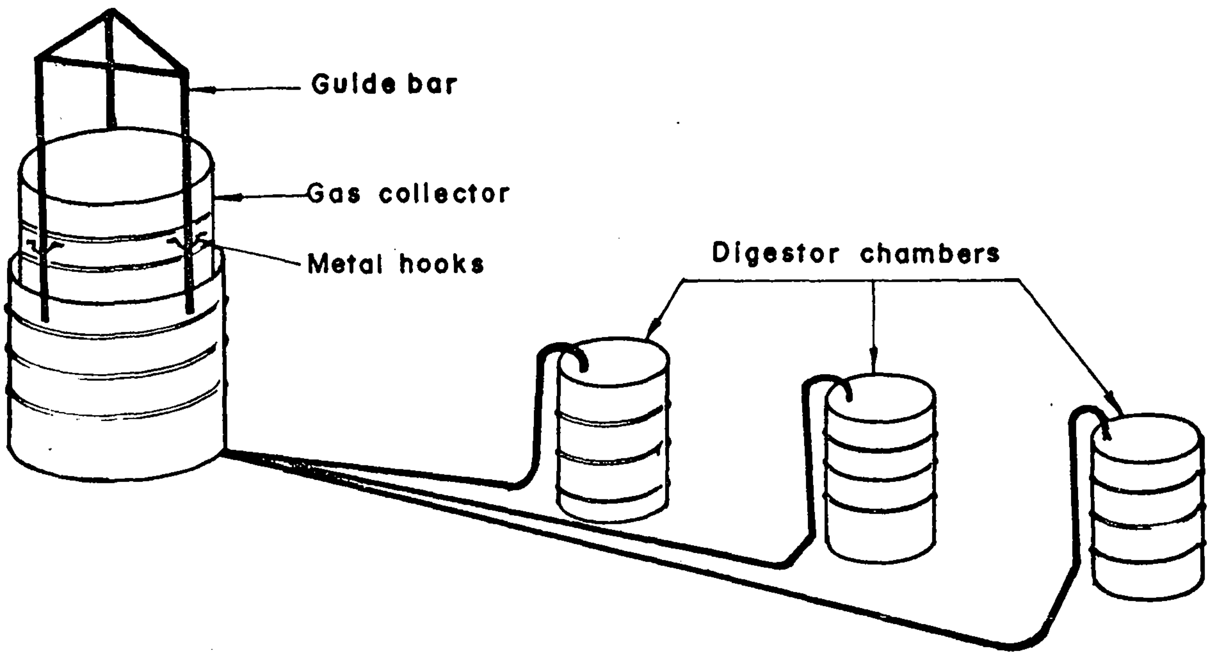
NEPAL MODEL

Botswana Model :

This model was designed by the Rural Industries Innovation Center in Botswana and is currently being installed in Botswana. A mixture of cow manure and water is the recommended feedstock although any animal manure could be used.

The unit consits of one or more sealed steel drums functioning as the digestion compartment connected by piping (tubing) to a gas collector storage tank. In order to ensure a steady gas production it is desirable to have two or more drum digestion compartments operating in a series connected to the gas collector.

The gas collector is made of one 30 gallon drum upturned in a 45 gallon drum full of water with 1 cm steel bars used to guide the rise and fall of the collector.



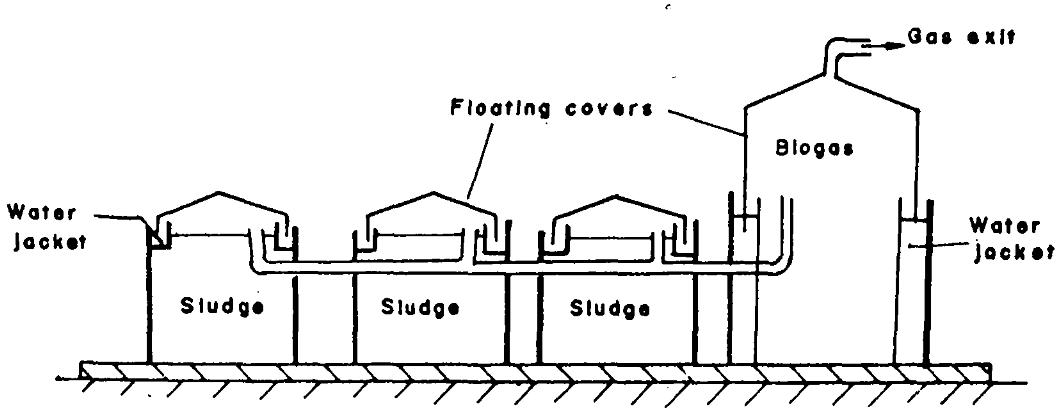
BATCH FED OIL DRUM FOR BIOGAS
(Botswana)

6.10 Some Latin American Plant Models

a) Guatemala-OLADE Model

This is a batch-fed plant based on the separate gasholder design. The digester is made of concrete and has a fixed steel cover. The cover can be removed while loading and unloading the digester. To obtain regular gas production, two or more digester units with a single gasholder can be used.

The input materials used are cow manure plus agricultural wastes like coffee and cocoa pulp. When loading the plant, the input material is put in the tank and then water is added to make a mixture of about 35% total solids. Generally



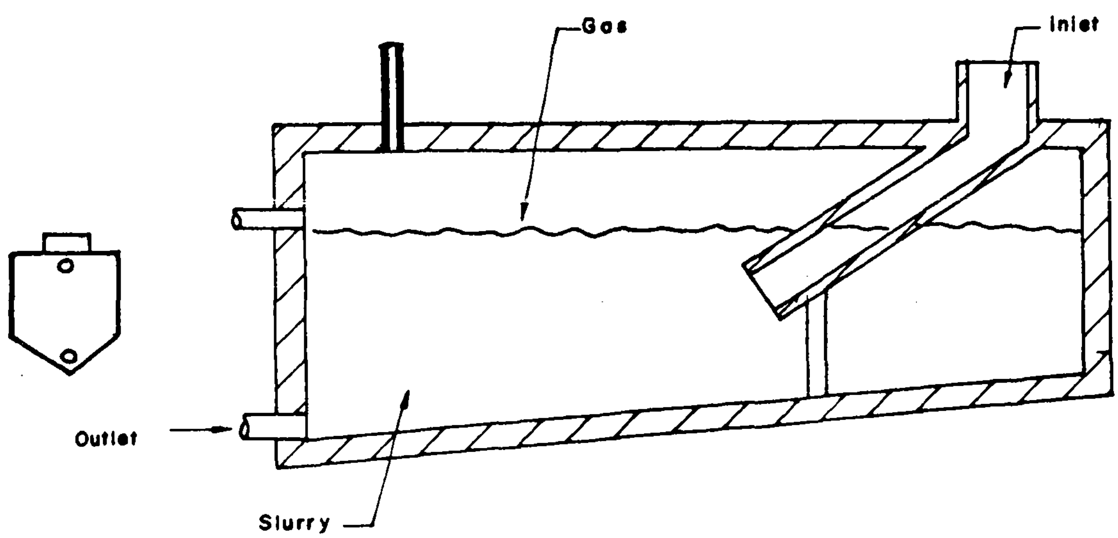
THE GUATEMALA – OLADE MODEL

the Retention Time is 2-4 months. If the tank is built above ground, the liquid sludge can be drained in the fields before unloading the solid sludge.

The Guatemala-OLADE is however, a very expensive one, especially with its steel cover for digesters and the steel gasholder. This model is the one selected by OLADE for demonstration in countries like Honduras, Nicaragua in Central America, Jamaica and Haiti in the Caribbean and Guyana and Bolivia in the South America.

b) Xochically-Mexico Model

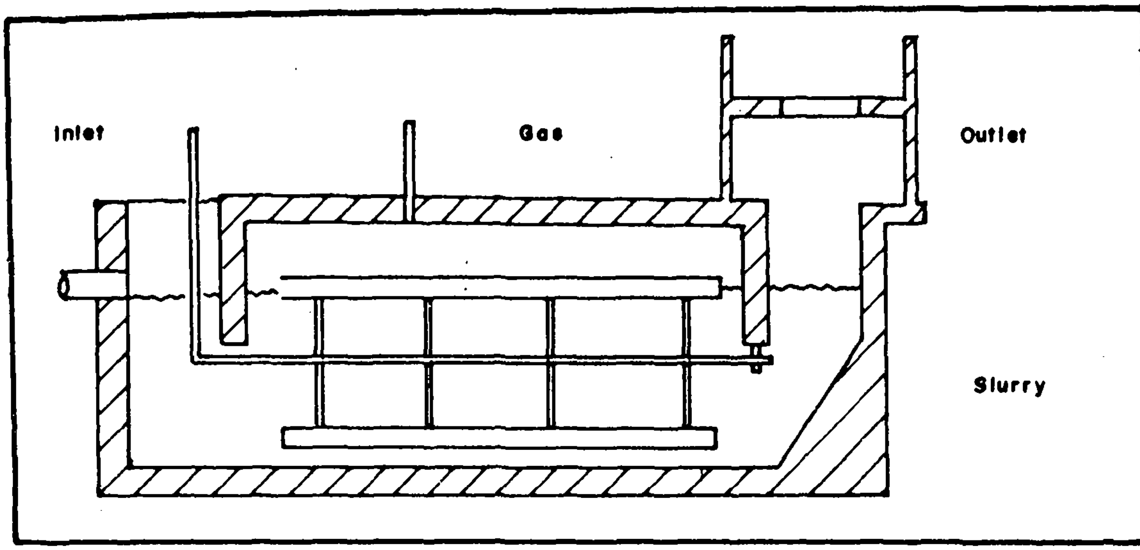
This model has been developed by Proyecto Xochically AC, a civil association of Mexico. It is a continuous-fed model and is one among those selected for demonstration in the Latin American and Caribbean countries under the OLADE biogas programme.



XOCHICALLY MODEL

c) CETA Model

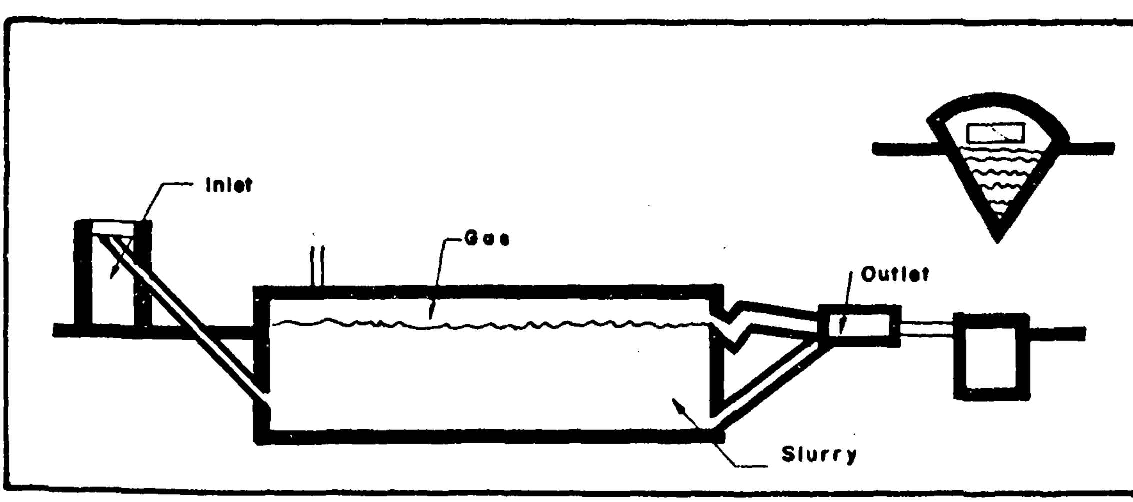
This model is developed by the Experimentation Centre on Appropriate Technology of the Engineering College, Unviersity of San Caulose, Guatemala. It is a continuous-fed model being installed for demonstration purposes in the Latin American and Caribbean countries.



CETA MODEL

d) IIE Model

Developed by the Institute de Investigaccones Electricas, Mexico, the model is being installed for demonstration in Latin America and the Caribbean.



IIE MODEL

CHAPTER - 7

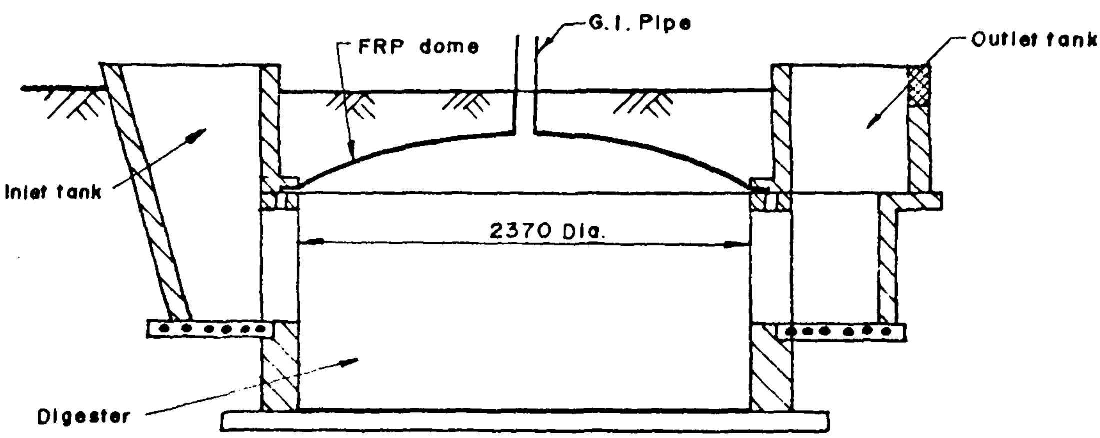
SOME EXPERIMENTAL PLANT MODELS

7.1 Gayatri Model

The Gayatri model is an improvement over the Janata Model. It has eliminated the use of the brick dome, and the use of cement is brought down to the minimum. Instead of the brick dome, a pre-fabricated Fibreglass Reinforced Plastic (FRP) dome of the same dimension is used for collecting the gas. The FRP dome being much lighter than the brick dome, the digester walls need not be made of cement. The model uses mud slurry for digester construction.

The Gayatri Model is less expensive than the Janata Model. Moreover, pre-fabrication and transportation of the dome are easy. Repairs, if necessary, are spot-oriented and easy. In addition, the prefabricated FRP dome facilitates standardisation and commercial production of the biogas plant. However, the success of the Gayatri Model will be subject to the availability of FRP.

A pilot-scale Gayatri Model plant of $2m^3$ capacity has been functioning satisfactorily at the Government Implement Factory, Bhubaneswar, India, for about a year.



GAYATRI MODEL (Capacity:-2 cum)

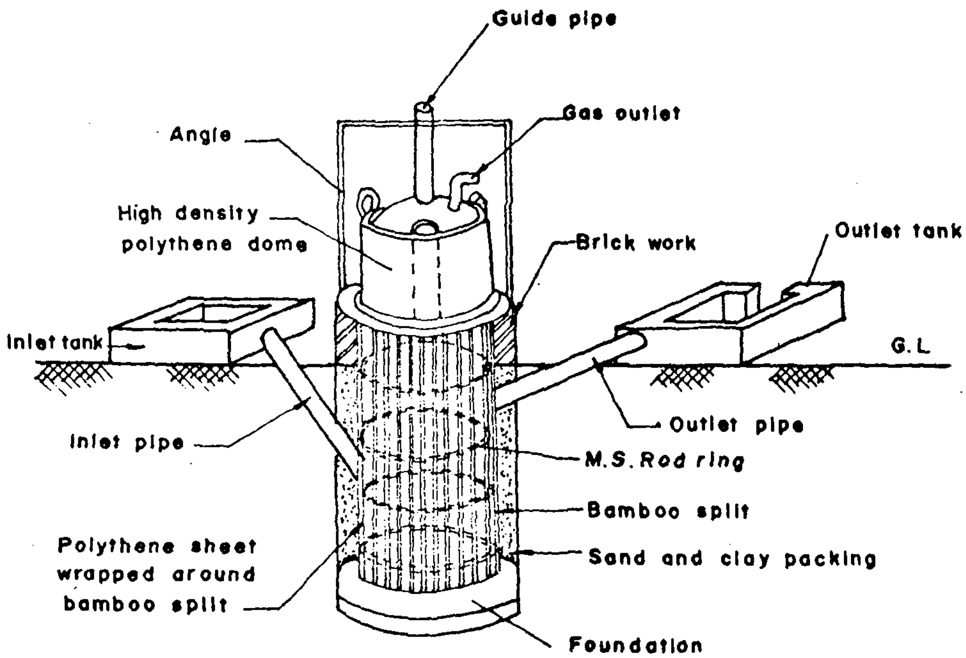
For further information, contact:

Government Implement Factory,
Satyanagar,
Bhubaneswar,
INDIA.

7.2 Bajwa-KVIC Model

The Bajwa-KVIC model, as the name indicates, is an improvement over the conventional KVIC model. Whereas the KVIC model uses the mild steel and cement for its costruction, the improved Bajwa-KVIC model uses only a few mild steel rods and no cement. The digester is made of bamboo strips, mild steel rods and Low Density Polyethylene sheets. The gasholder is made oı High Density Polyethylene sheets.

The bed of the digester pit should be levelled and compacted and all sharp objects like stones, pebbles, roots, etc., removed in order to prevent puncturing the LDPE sheets. A layer of fine sand should be spread over the bed to provide a smooth and plain cushon for the polyethylene film. Depending upon the size of the plant a skeleton of bamboo splits with a few mild steel rod rings around them are fabricated in the pit. The floor of the digester is also made of the same bamboo-split-mild steel rod skeletal frame. The LDPE sheet is wrapped around the skeletal frame. A packing of the soft excavated earth and clay is made around the digester for compaction. The packing of the digester above ground level can be of brickwork.



BAJWA — KVIC

The gasholder, as in the KVIC model is a floating drum guided by a central guide pipe.

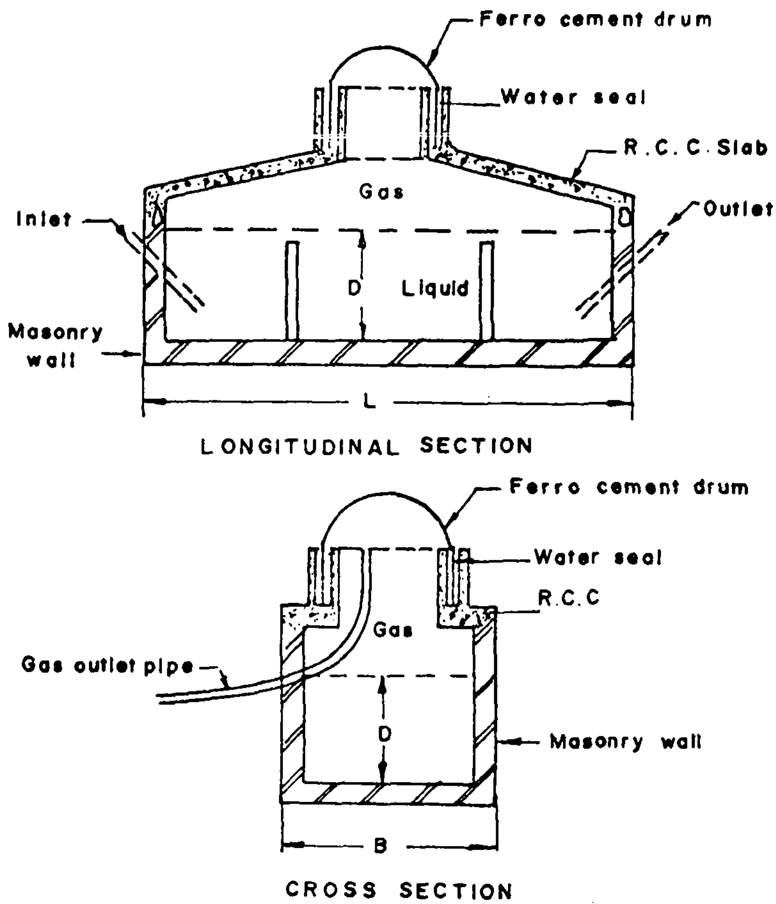
The Bajwa-KVIC model facilitates reduction in time and cost of plant construction. The gasholder is very light and does not require periodical maintenance. Repair is possible at the spot, using a kerosene blow torch. Plant construction is easier since locally available materials like bamboo split is used and costly items like cement and mild steel have been reduced to the minimum. Transportation of HDPE and LDPE sheets and mild steel rods to remote areas is easy. The LDPE sheets are found to check water seepage better than cement or brick.

However, the life expectancy of the HDPE gasholder, due to its exposure to ultraviolet rays, tends to be short.

A small size pilot scale ($2m^3$) plant of this model has been commissioned at the Government Implement Factory, Satyanagar, Bhubaneshwar, India. Further information regarding this model can be had from C.V. Krishna of the Government Implement Factory.

7.3 Manipal Model

The Manipal Model is a blend of the Indian and Chinese models. The digester is in the form of a rectangular tank built of masonry, with a flat but sloping RCC roof. The gasholder is integrated with the digester and the sloping roof permits a large capacity for holding biogas over the slurry, with a small increase in the depth of the tank. Pressure control is effected by a shallow ferro-cement cover of



MANIPAL MODEL

design weight on top of the sloping roof slab. The ferro-cement cover is dipped in water seal. The cover rests on annular space provided on a man-hole and thus facilitates inspection, scum breaking, cleaning, etc. Inlet and outlet pipes can be designed according to the nature of the feed material used and the mode of operation (continuous/ batch). Biogas is drawn through a pipe provided internally.

The masonry wall and the RCC slabs must be rendered leakproof and be designed to withstand the pressure of the slurry. The ferro-cement gasholder and the annular rings holding it must also be made leakproof. Moisture condensate taps can be provided to the gas mains as in other models. The digester can be built either completely or partly, under the ground or above the ground, depending on the location.

The Manipal Model is economic since it replaces the large-size mild steel gasholder with a small ferro-cement one. Moreover, the ferro-cement gasholder can be of uniform size, irrespective of the size of the plant, which facilitates standardisation and prefabrication. Similarly, the annular ring for holding the ferro-cement gasholder can also be prefabricated.

The rectangular masonry digester and the sloping RCC slabs are easy to construct and maintain. The depth of the digester can be adjusted to suit local geographical conditions. The plant can be run on any feed material by suitably changing the inlet and outlet devices. Repair and maintenance of the plant is comparatively easy.

For further information, contact

G.R. Raghunath Rai,
Prof. of Civil Engineering,
Manipal Institute of Technology,
Manipal - 576119,
INDIA.

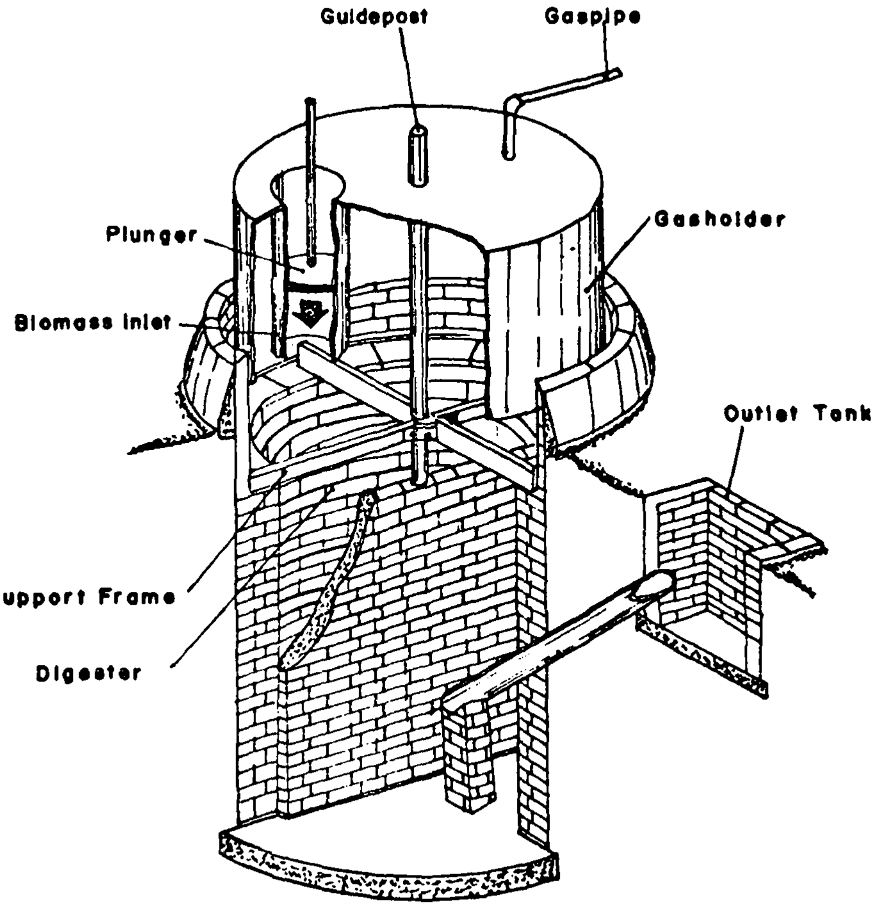
7.4 Jyoti Top Loaded Digester

This model, designed by the Jyoti Solar Energy Institute, India, is a modified KVIC model suited specifically for the digestion of agricultural and forestry residues. In this model, fresh biomass is fed through the top of the gasholder to the surface of the slurry by means of a plunger arrangement. This top loading ensures that the heavier, partially digested biomass can settle at the bottom of the digester, unimpeded by the lighter fresh biomass fed into it.

The inlet tube will be always in contact with the slurry, even when the gas-holder is at a maximum height, so that no gas can escape. Stirrers are provided through the central guidepipe with paddles near the surface as well as preventing the rotation of the mat as a whole. The gasholder moves inside a peripheral channel near the top of the digester. The Jyoti model thus solves the scum formation problem which is acute in the case of agricultural wastes digestion. Besides, the model also eliminates the need of finely shredding or drying of the residues.

For further information, contact:

Mr. J.H. Patel,
Jyoti Solar Energy Institute,
Birla Vishva Karma Mahavidyalaya,
Vallabh Vidyanagar,
INDIA.



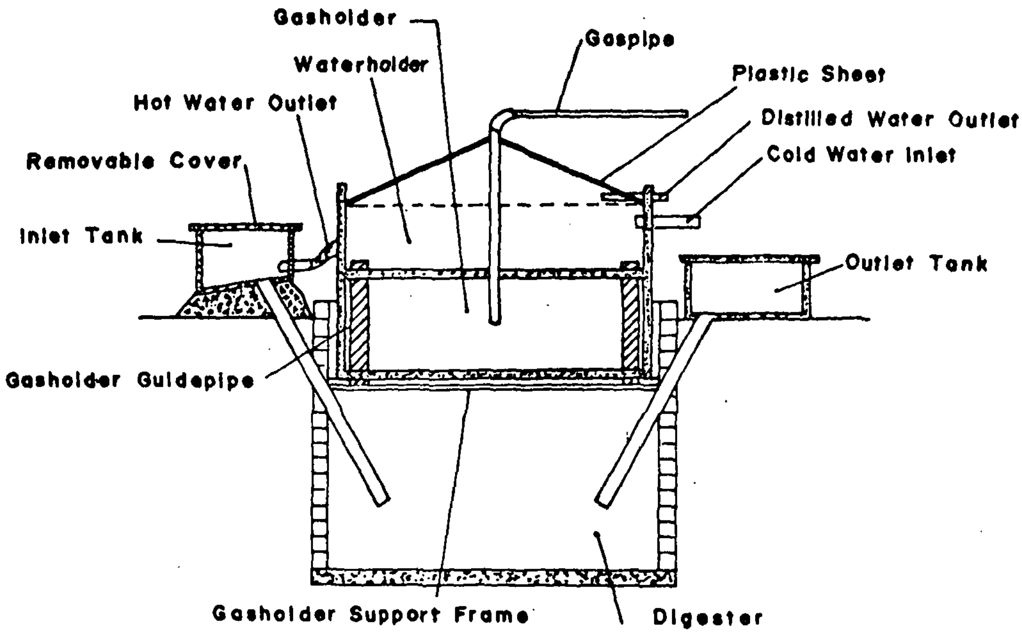
JYOTI – Top loaded digester

7.5 ASTRA Model

The ASTRA Model has been developed by the Cell for Application of Science and Technology to Rural Areas of the Indian Institute of Science, Bangalore, India.

Basically, a variation of the floating gasholder design, the ASTRA model incorporates a solar water heater and a solar still. The mild steel sides of the gasholder are extended to 0.3 m above the black painted roof, thus forming a 0.1 m deep water pond on the roof of the gasholder. The pond is covered with a polythene sheet. By making the transparent cover assume a tent shape, the roof-top solar heater can serve the additional function of a solar still to yield distilled water. Further, the model has a lower retention period (35 days), with the dimensions of the digester and the gasholder optimised for minimum cost.

The merits of the ASTRA model are its reduced retention time, with subsequent cost reduction, and the provision for maintaining optimum slurry temperature in



ASTRA Model

a cold climate.

However, the use of *mild steel* for gasholder construction still poses problems of corrosion, high cost of the material, difficulties in transportation etc.

The ASTRA model is still in the experimental stage. Its performance in large-scale systems is yet to be monitored.

For further information, contact:

Dr. A.K.N. Reddy,
Covenor, ASTRA,
Indian Institute of Science,
Bangalore 560 012,
INDIA.

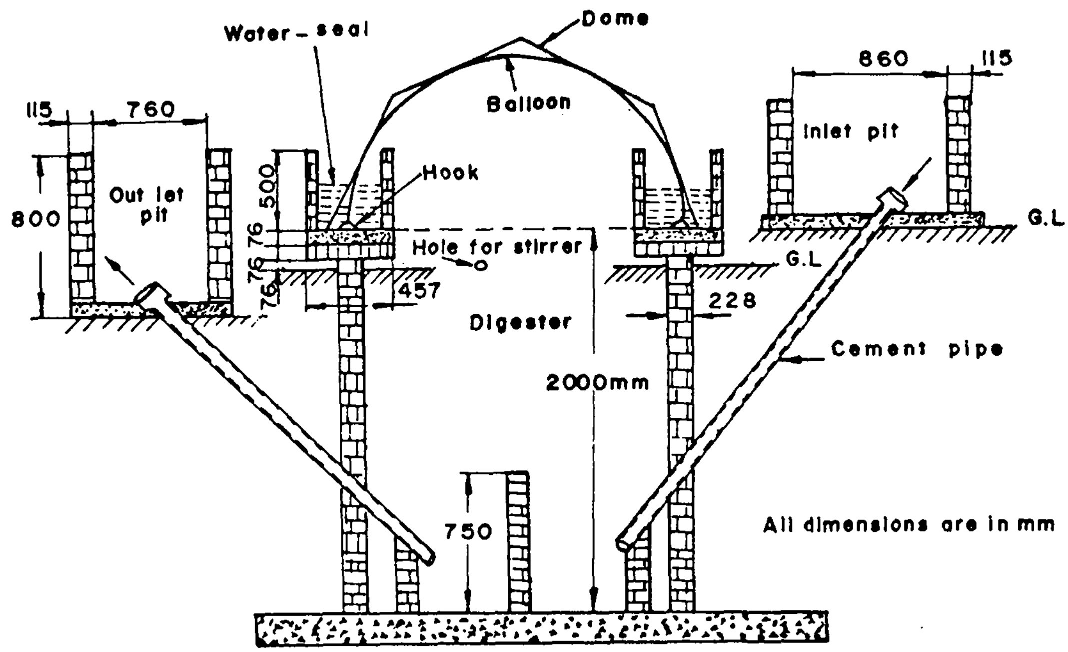
7.6 Jwala Biogas Plant

Developed by the AMM Murugappa Chettiar Research Centre, India, the Jwala biogas plant is a variation of the floating gasholder design.

The digester is the KVIC type, with a low density polyethylene (LDPE) sheet together with a geodesic balloon constituting the gasholder. The function of the geodesic dome is to support the inflated sheet. The sheet is secured to the dome and the dome is in turn held inside a waterseal to avoid gas leak. The height of the waterseal also controls the pressure.

Scum breaking is achieved by means of a *stirrer which has both reciprocatory* and rotary motion. The stirrer rod passes through a guiding tube the end of which is immersed in the slurry to prevent gas leakages.

The digester is in the form of a circular well below the ground level. The inlet pipe enters the partition wall tangentially so as to give a better dispersion of heavy materials like sand. Once the desired height of the digester is reached, the water-seal is built above it by preparing a concrete



JWALA MODEL

base. The balloon should be installed only after the digester is filled with the charge and the eruption of gas bubbles is observed all over the surface. This is necessary as, in the absence of sufficient gas, the balloon is in a sagging position and can be easily damaged.

The Jwala model is considerably cheaper because no costly materials are involved in its construction. Moreover, the gasholder can be fabricated locally and can be transported to any remote area. The gasholder is easily removable and replaceable and the LDPE sheet used for the gasholder neither requires regular maintenance nor highly skilled personnel for construction.

The model is being field-tested in a number of villages in Tamil Nadu, India.

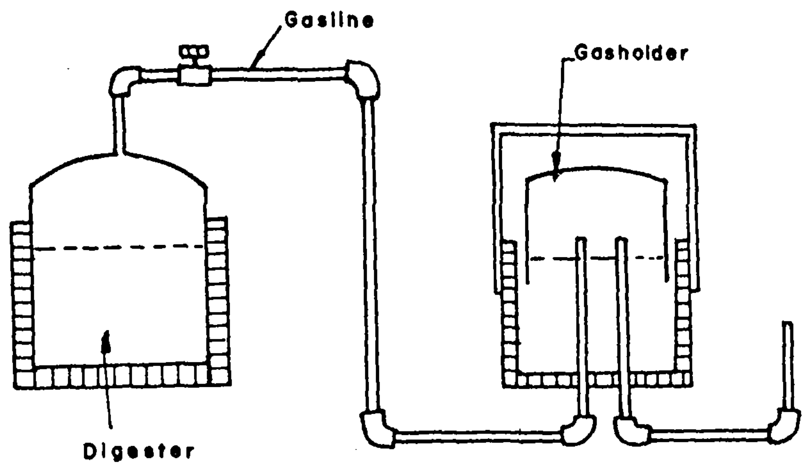
For further information, contact:

The Director,
AMM Murugappa Chettiar Research Centre,
Photosynthesis & Energy Division,
Tharamani,
Madras 600 042,
INDIA.

7.7 Belur Math Model

This model was developed by Swami Vimuktananda at the Ramkrishna Mission Saradapitha, Belur Math, Howrah, West Bengal.

Based on the separate gasholder design, the Belur Math model consists of a digester which is a simple pit dug in the earth; it can also be built either with bricks or sheets. It has an inlet and an outlet and a gas-proof metallic cover. The



BELUR MATH GAS PLANT

gasholder consists of two cylindrical tanks, one inverted over the other. The lower one is filled with water. A gas-pipe runs through its bottom to above the water level. The lower end of this pipe is connected with the heating or lighting devices.

The slurry is fed into the digester daily. Biogas produced passes through a pipe to the gasholder and from there to the utilisation device.

For further information, contact:

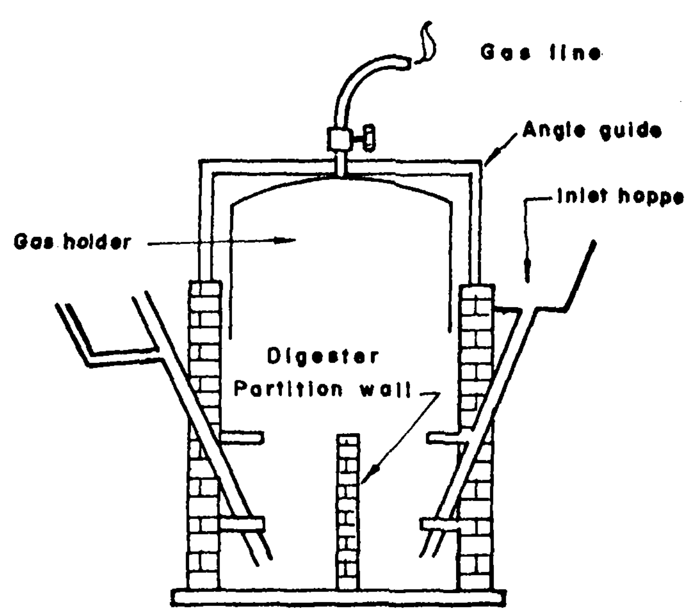
Ramakrishna Mission Saradapitha,
Belur Math,
Howrah,
West Bengal,
INDIA.

7.8 NEERI Model

The model developed by National Environmental Engineering Research Institute, India, is a variation of the floating drum gasholder design.

The digester is a masonry structure partly above the ground and partly below the ground with a floating drum at the top to collect the gas.

The plant is intended to run on night soil. There is provision in the digester for intake of night soil slurry and removal of sludge.



NIGHT – SOIL BIOGAS PLANT

Night-soil and water in the ratio 1:1/2 is fed into the digester after screening through a 2.5 cm mesh screen. 10 lbs of slaked lime may be added in the beginning for acceleration of gas production. The sludge is removed periodically into a sludge drying bed for dewatering and drying. The supernatant of the digester and the underflow of drying beds are further treated in a stablisation pond.

For further information, contact:

The Director,
National Environmental Engineering Research Institute,
Nehru Marg,
NAGPUR - 440 020.

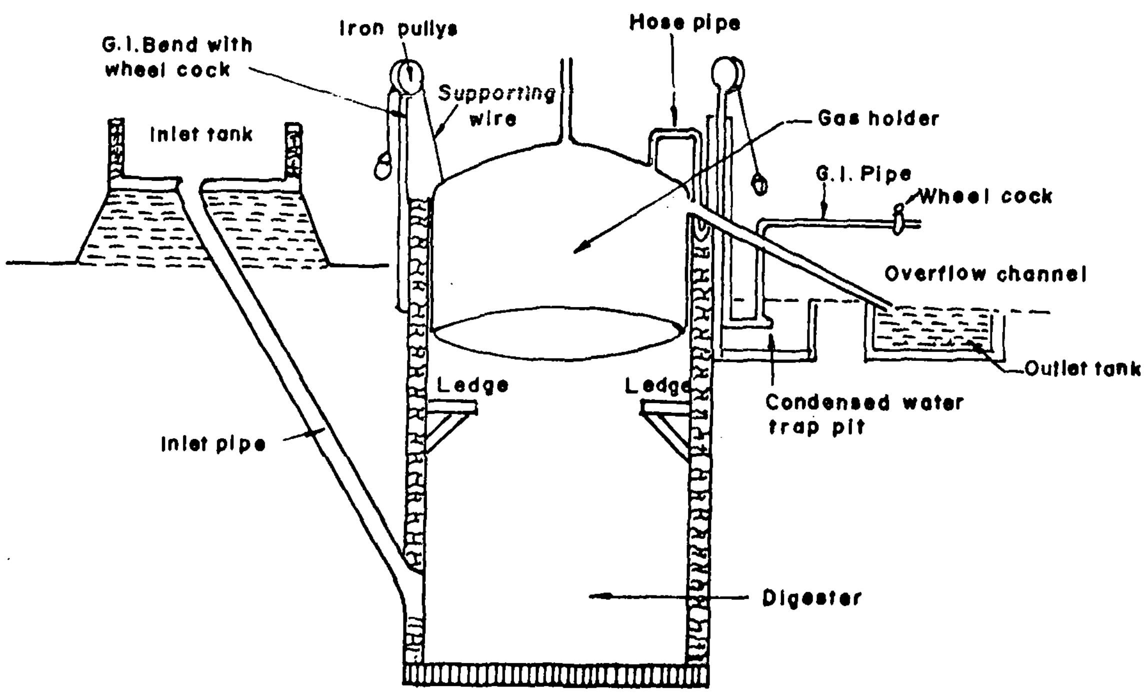
7.9 IARI Model

The IARI Model was the first biogas plant model to be designed in India.

counterpoise buckets with a wire pulling system are also provided.

The digester is made of bricks and masonry while the gasholder is of mild steel.

The present village model biogas plant at the IARI consists of a digester which is a brick-lined slurry wall of 3.66 m in depth and 1.68 m in diameter with a floating mild steel drum, 1.5 m in diameter and 1.2 m in height, introduced upside down into it. The drum acts as a gasholder which rises up and floats upward when gas accumulates. Feeding is done through a funnelshaped inlet pipe. Gas is let out for use through an opening in the top.



IARI BIOGAS PLANT

The plant consists of a floating drum gasholder introduced upside down into the digester. In order to hold the gasholder in proper position and to balance its weight,

A small brick-lined pipe 30 cm x 30 cm just outside the well serves as a water catchment to remove the condensed moisture from the gas pipe.

CHAPTER - 8

PLANT MODELS FOR SOLUBLE WASTE WATERS

Anaerobic digestion of soluble, low-strength wastes like food processing waste waters, dairy whey, etc., requires specially designed plants. For essentially soluble waste waters, improvements in plant models have been achieved by two broad approaches:

The first is to increase the density of the bacterial population in digesters. This is done by retaining the biomass within the digester for periods longer than the waste undergoing digestion. This increases the retention time of anaerobic bacteria in digesters relative to the liquid being treated.

The second approach is to increase bacterial activity by selecting optimal digester operating conditions, and by ensuring an adequate supply of all known essential nutrients.

The former has certain implications on plant models and hence is discussed below. Individual bacterial cells are so small (around 1 to 5 microns in size) that they tend to remain freely suspended in watery wastes. Retaining the bacteria for longer periods requires a means of solid/liquid separation. Two mechanisms for achieving this separation, and maintaining elevated biomass densities in digesters, have been:

a) Providing conditions within the digester which enhance the natural tendency of biomass to form aggregates (flocs) which are large enough to be separated from waste water by settling.

b) Providing surfaces within digesters to which bacteria can attach in films. The bacterial support materials are themselves retained in digesters by gravity or by tight packing.

8.1 Floc-based Digester Designs

a) Anaerobic contact process: The first method of increasing the digester biomass level was the anaerobic contact process. In this method, the effluent from a conventional mixed digester passes to a settling tank in which the flocculated digester biomass, together with undigested feed solids, are settled and returned to the digester.

The separation and concentration of biomass flocs prior to their return to the digester is ensured by various methods like gravity settling in a thickener; gravity settling in a lamellar separator; gravity settling of polymer enhanced flocs; centrifugation; flotation; vacuum degassification; aeration; thermal shock; and low level turbulence caused by a packing material, etc.

The Anaerobic Contact Process enables moderate biomass densities and cell residence time (5-10 days) to be maintained while reducing waste residence time to less than one day. With low to medium strength wastes digester biomass densities of 5-10 g VSS l^{-1} are usually obtained, and space loadings of 2-6 kg COD m^{-3} d^{-1} rarely exceeded. Using high strength wastes biomass densities of 20-30 g VSS l^{-1} and space loadings of 5-10 kg COD m^{-3} day^{-1} have recently been obtained.

Contact processes digesters being marketed today include those manufactured by Biomechanics Pvt. Ltd. (Bioenergy process) and A.B. Sorigona (Anamet process).

b) Clarigester: The Dorr-Oliver reverse flow clarigester is a variation of the contact process, with the settling compartment located above the digester. Unlike the contact process, the digester is not mixed mechanically or by gas recycle. Raw waste enters at the base of the digester via a number of inlets located around the perimeter, and via a rotating feed pipe, and flows upward through a dense bed of flocculated bacteria. On entering the settling compartment, flocs collect and return to the digester by gravity, if necessary assisted by a mechanical rake in the settler.

While only modest biomass densities (19 g l^{-1}) and space loadings (3 kg COD m^{-3} day^{-1}) are achieved with a soluble high strength waste (COD 20,000 mg l^{-1}), this design is important as the first upflow sludge blanket design. High COD conversions of 97-98% are obtained, possibly as a result of the partial "plug-flow" characteristics of the waste in the digester. Like the contact process, the main limitation of this process is associated with floc retention.

c) Upflow anaerobic sludge blanket (UASB): The UASB process depends on the development within the reactor, of highly settleable biomass; either as flocs or as dense granules 1-5 mm in size. This is achieved through a carefully controlled initial start-up procedure in which undesirable low density seed sludge components are allowed to wash out of the reactor while active biomass with better settling properties is retained. A dense bed of granular sludge usually develops at the bottom of the reactor, with biomass concentrations exceeding 60 gTS l^{-1}, while flocculent biomass extends above this, thinning out to about 10 gTS l^{-1} near the gas-liquid surface. No mixing is imposed on the reactor as this is believed to adversely affect biomass aggregation. Rising gas maintains biomass granules and flocs in a more or less fluidised state, and the resulting turbulence aids in detaching gas bubbles from flocs in the upper part of the digester. Simple baffle arrangements assist in retaining biomass within the digester by creating a quiescent region in which entrained flocs can separate from the liquid before it leaves the digester via a number of weirs.

The liquid which moves upwards through the granular sludge bed in a plug-flow mode with some bypassing, is well-mixed in the floc blanket region, and again moves in a plug-flow mode through the settling region. The design of UASB reactors ensures a uniform distribution of raw waste around the base of the digester, sufficient cross section to prevent excessive biomas entrainment, and an effective separation of gas, biomass and liquid.

The UASB is a simple design, and does not require the expense and energy consumption of recycle pumps, centrifuges or biomass support media. It has been successfully applied on a pilot scale to slaughterhouse waste, raw sewage, cannery waste and the stillages from sugarcane and sugar beet fermentation. The process is engineered and marketed by a number of firms in Europe and the U.S.A.

d) Anaerobic filter: The "anaerobic trickling filter" was devised by Young and McCarty, and embodies the concept of biofiltration already used in the aerobic trickling filter of sewage treatment plants.

The filter consists of an upflow reactor filled with a bed of 1-1 1/2 in. stones. The stones were originally intended to provide a fixed surface for biomass attachment, as in the aerobic trickling filter. However, it has repeatedly been observed that a major portion of the biomass is not attached to the stone packing, but lies loosely (in flocs) in the interstitial spaces from which it can be washed without difficulty when the stones are removed from the filter or during high hydraulic loads. It appears that when bacterial flocs are buoyed by attached gas bubbles, these separate when the rising floc hits an overlying stone. The floc then returns to its original position, and the gas bubble continues to rise.

In early applications of anaerobic filters low-medium strength wastes (COD 1000-6000 mg l^{-}) were tested. With stone used as a packing, biomass densities of 10-25 g VSS l have been obtained although space loadings have generally not exceeded 6 kg COD m^{-3} day^{-1} for acceptable (70%) COD conversion.

More recently, the anaerobic filter has been improved through the use of high voltage (0.8-0.9) packing materials. With high strength soluble wastes, high loadings have been achieved with moderate (70%) COD conversion and good process stability. The filter has been applied commercially to the treatment of wheat starch and chemical waste waters, and is marketed in the U.S.A. by Celanese Corporation who have apparently developed packing materials of high voidage and acceptable cost.

Attached-film Digester Designs

This approach appears to derive from the tricking filter process. In this process, stones, plastic sheets or special plastic pieces become coated with a film of micro-organisms which breaks down waste as it passes through the reactor.

In order to increase bacterial densities, efforts have been made to maximise the surface area for bacterial attachment. One approach has been to decrease the support particle size from 20-40 mm to 0.5-1.0 mm, giving a 30-60 fold area increase. By fluidising a bed of these particles with waste pumped up through it, bacterial film thickness is controlled and blockages avoided. Two designs based on this principle are the expanded bed and fluidised bed digesters.

a) Anaerobic attached-film expanded bed (AAFEB) reactor: This process consists of a reactor filled with a fine (0.5 mm) granular material to which biomass adhere in a thin film. The granular support is partly or fully fluidised by the upward flow of recycled reactor contents.

Support materials include PVC beads, ion exchange resins and porous alumina. Low upflow liquid velocities are employed to give a bed expansion of 10-20%.

The process was initially applied to synthetic and real primary settled sewage, with extremely low strength wastes (150-600 mg COD l^{-1}). At 30°C, 60-70% conversion of synthetic sewage of strength 400-600 mg COD l^{-1} was obtained at space loadings to waste residence times of 30-60 minutes. Even at ambient temperatures (20°C), the rate of digestion of this waste water was most impressive. These results suggest the possibility of the anerobic treatment of raw sewage, previously considered impractical because of its extremely low strength.

More recently, the expanded bed attached film process has been applied to a high strength soluble waste, dairy waste. COD removal better than 85% was obtained at space loadings of 10-20 kg COD m^{-3} day^{-1}, while stable operation was obtained up to 60 kg COD m^{-3} day^{-1}, at the expense of waste conversion. Laboratory studies on this process are continuing.

b) Fluidised bed reactor: The fluidised bed process differs principally from the expanded bed type in the degree of bed expansion used, ranging from 30 to 100%. In much of the early work quartzite sand of particle size of 0.5 mm was used.

Very high space loads (20-30 kg COD m^{-3} day^{-1}) have been sustained with a variety of medium and high strength soluble wastes, with COD removals ranging from 70-90%.

These systems are being marketed by Dorr-Oliver and Biojet International.

c) Stationary fixed-film reactor: in this process a biomass support material is arranged in a fixed, vertical, straight channel or tube, with waste flowing either up or down the reactor.

Support materials, including needles, punched polyester, baked potters clay, drainage pipes, PVC sheeting and glass, have been fashioned into tubes or channels of a diameter of 20-100 mm and height of 600-1100 mm, giving areas for attachment from 50 to 250 m $-m^{-2}$. Similar work by the Corning Glass Company has resulted in the development of porous biomass support materials with pore sizes matched to the bacterial cell size.

A stable performance has been achieved with space loadings of 10-20 kg COD m^{-3} day^{-1} and COD conversions of 85-92%. Specific biomass activities similar to those in UASB reactors, have been measured.

When used in the upflow mode, liquid flow is laminar at the reactor base, with mixing increasing up the tube as a result of gas evolution. Significant accumulation of biomass flocs occurs so that, in this mode, this process closely resembles the anerobic filter. In the downflow mode, excess biomass is removed from the support surface by fluid shear, preventing blockage of the channels. Compared to fluidsed bed reactors, the reduction in liquid recycle is an advantage as the closer approach to plug-flow results in higher waste conversion at a given specific loading, and a reduction in the process energy requirement. The effect of packing material cost on the overall process economics is not known at present.

CHAPTER - 9

UTILISATION OF BIOGAS

9.1 Fuel Characteristics

Biogas is a mixture of several gases like methane, carbon dioxide, hydrogen sulphide, and traces of hydrogen, nitrogen, carbon monoxide, etc. It has the following properties:

- it is non-poisonous in nature;
- it has no offensive smell;
- it burns with a clean blue sootless flame;
- its critical pressure and temperature are 42 atmospheres and -82°C respectively.
- its caloric value is 4,700-6,000 kcal/m^3 (20-24 MJ/m^3);
- its flame speed factor is 11.1;
- its inflammability in air; 6-25% of biogas mixed with air will burn : consumption in chapter 18
- its thermal efficiency in a standard burner is 60%.

9.2 Use as Substitute Fuel

The presence of methane in biogas renders it combustible. Its inflamability in air and high calorific value make it a safe and good source of fuel. Presently, biogas is being used for cooking, lighting and powering engines. The rate of biogas consumption for various purposes is given in Chapter 18.

9.3 Biogas Stoves

Biogas cannot be used on devices intended for natural gas or any petrol-based gas. The flame speed factor of biogas is lower than natural gas and hence when biogas is used in a burner built for natural gas, the flame tends to lift off from the burner. Biogas fed at a lower pressure would stay on the burner, but may not burn efficiently.

Biogas stoves should have the following characteristics:

- Inlet channels should be smooth to reduce the resistance to flow of gas and air;
- Spacing and size of air holes should be suitable;
- Volume in the channel where the gas and air mix should be large enough to allow complete mixture;
- Gas jet holes should not be too large but should allow easy passage of the mixed gas and air, to allow complete expulsion;
- The appliance should be simple, economical and cheap to make.

While designing a biogas stove, the following characteristics of the biogas are to be considered:

- composition of biogas (generally 60% methane and 40% carbon dioxide)
- pressure of the gas (8.75-10cm water column)
- flame velocity.

The following rules should be observed while designing:

- Air must be thoroughly mixed with gas before it reaches the flame ports and should flow near the gas jet, ideally with a venturi. (In the absence of sufficient air there is a smell from the burning gas).
- Total area of the flame ports should be between 8-200 times the area of the gas jet.
- Distance from the flame ports to the surface of the cooking pot should be between 2.5 cm-3.0 cm.
- Supports for cooking pots should not prevent air from getting to the flame.
- To allow cross-lighting from one flame port to the next, the distance between flame ports should not be more than 2.0cm.
- To prevent backfiring, the thickness of materials at the flow cork should be about 1.0cm.
- For corrosion-resistance properties, cast iron is better than mild steel.

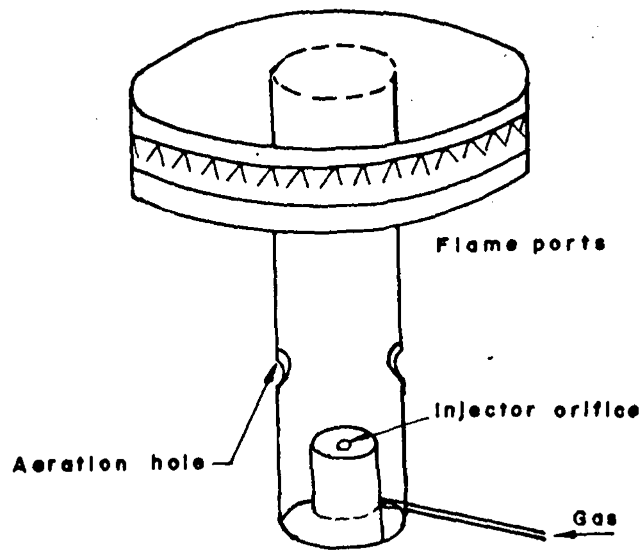
Given below are the specifications for a 0.45 m per hour biogas stove for domestic use:

Jet size - 2.25 mm dia.
Area of jet - 3.98 mm^2
Flame port size - 6.0 mm dia.
Number of ports - 20
Total area of ports - 565 mm^2
Ratio of jet area to flame port area - 1:142
Length of gas mixing pipe - 20mm
Diameter of gas mixing pipe - 20mm

9.3.1 Some Stove Models

a) Watson Type Burner

Purpose: Domestic use
Flame port area to injector area ratio - 300:1
No. of ports - 36
Flame port size - 0.114 inch dia
Injector size - 0.038 and 0.041 inch



WASTON-TYPE BURNER

Gas pressure required - 3-20.5cm water gauge

Comments: Efficient stable flames can be obtained.

b) IARI Burners

i) Tin Burner

Purpose: Domestic use.
Material needed: Empty cigarette tins.
Construction: By boring a hole 0.7 cm in the side of the cigarette tin, about 2 cm from the bottom solder a 7cm long tube of this diameter, with 3 cm inside and 4 cm outside. The lid is perforated with a 2 mm nail in a circle of 4 holes with one hole in the centre. The tin is filled with a few stones for gas distribution. Gas passing inside the tin through the tube

burns from the perforations at the top and yields a good flame for cooking. The burner is introduced in an earthern 'Chulah' on which the cooking pot is placed.

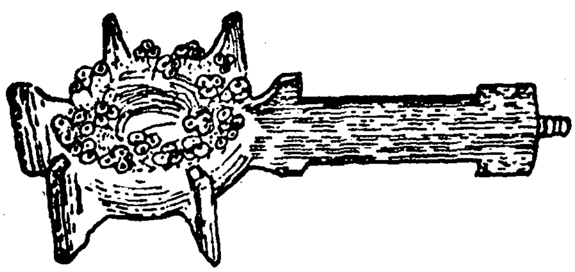
Comments: This stove model is less effcient, with low temperature. Moreover, it has a tendency to rust quickly.

ii) Angithi Burner

Materials needed: Flat tins of the size of the usual boot polish tins or larger flat tins.

Designing: A 0.7 cm metal tube bent at a right angle is soldered in a hole made in the bottom of the tin. The cover of the tin is perforated with 2 m holes.

Gas consumption: 1130 l/hr.



GOBAR GAS ANGITTI BURNER
(1130 litres/hr)

Remarks: Both the Angithi burner and the tin burner have the same defects.

iii) Low-Cost Burner

Purpose: Can be arranged to suit various purposes.
Material used - Cast iron.
Length of gas mixing pipe - 15 cm.
Diameter of mixing pipe - 0.6 cm.
Jet size - 0.2 cm.
Flame temperature obtained - 75°C.
Gas consumption - 2-4 fl/hour at usual gasholder pressures
Maximum efficiency - 75% (under optimum conditions)

Modifications :

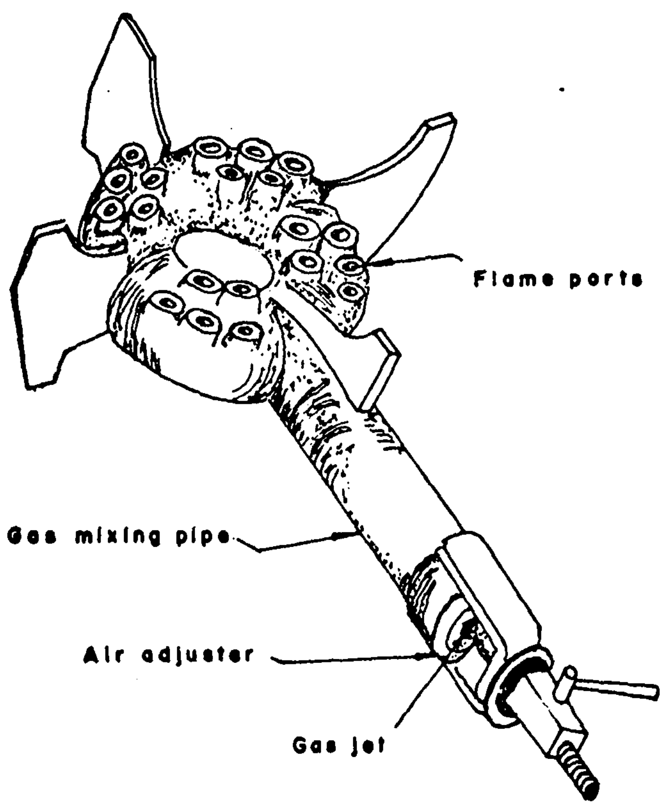
(1) Double burner model can be used for domestic purpose. Permanent ovens (group cooking, i.e. mess, hotels)

(2) The burner with the supporting pipes can be directly fitted over the gas line, projecting upright. A brick and clay surrounding makes the oven complete. Since the capacity of the burner required for such models is much higher, 7.5 cm or 10.0 cm diameter burners could be used for this design.

iv) Normal Biogas Stoves

Utility quality

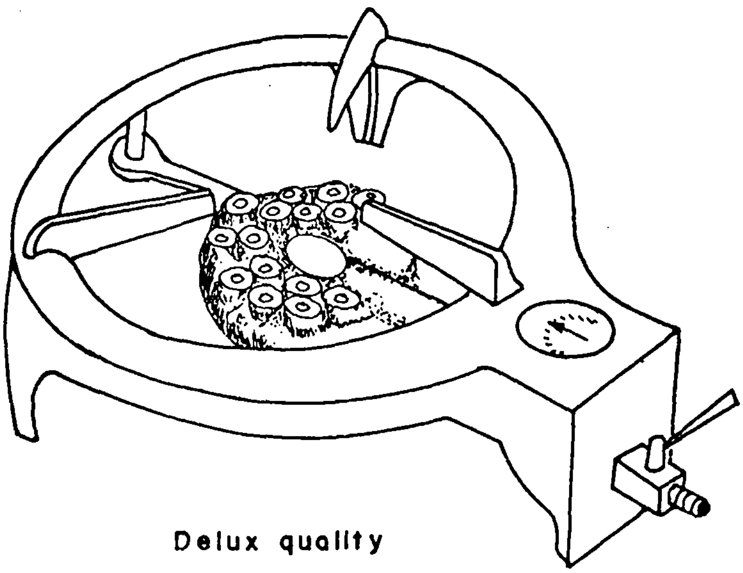
Purpose - Domestic use
Gas consumption - 225 l/hr
Efficiency - It burns with an intensity equal to half that of a kerosene pressure stove.



Utility quality

Deluxe quality

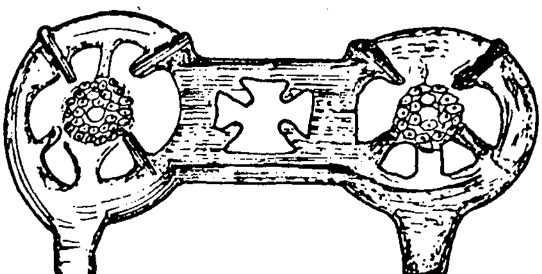
Purpose - Domestic use
Gas consumption - 450 l/hr



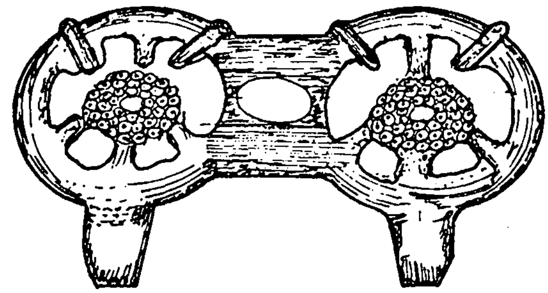
Delux quality

v) Gobar Gas Double Deluxe Burner

Purpose - Domestic use
Description - 2 burners available
Gas consumption - 450 l/hr each
Efficiency - Equal to that of a kerosene pressure stove



GOBAR GAS DOUBLE DELUX BURNER



GOBAR GAS DOUBLE DELUX BURNER

(Economy-Size)

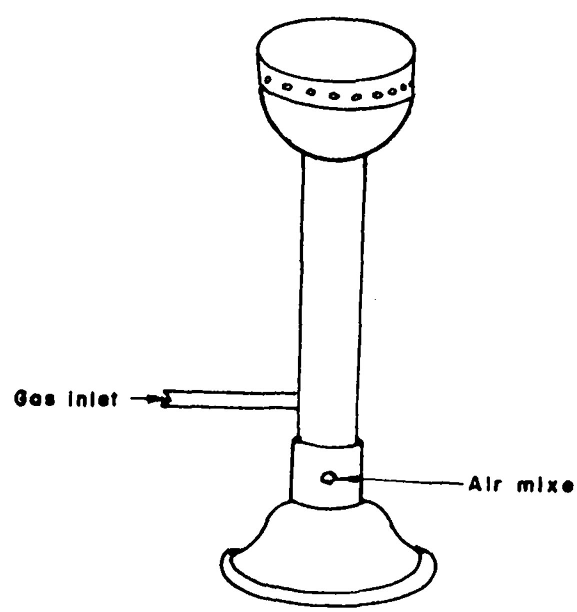
vi) Gobar Gas Double Deluxe (Economy Size).

Purpose - Domestic use
Description - 2 burners available
Gas consumption - 450 l/hr for one burner and 225 l/hr for the other

c) **Fischers' Burners**

Purpose: Domestic use

Length of gas mixing pipe - 15-25 cms (The length is determined by the size of the container (stove) which supports it)
Diameter of gas mixing pipe - 1 cm



FISCHER'S BURNER

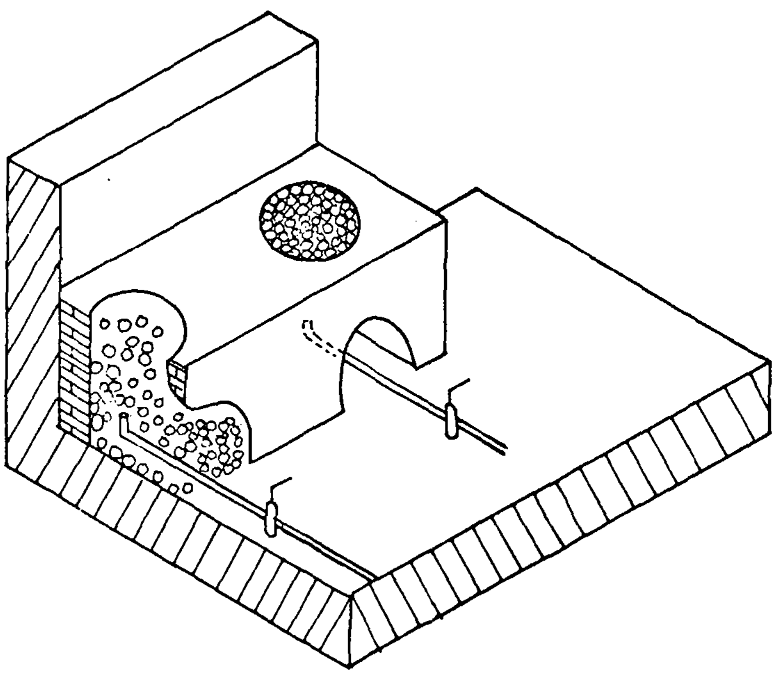
Description - The pipe can be secured to the stove in any satisfactory manner with bolts and wire. When properly situated in the stove, the flame spreader support will rest at a distance of 2.5 cm below the vessel to be heated. An ideal spreader support is a bicycle bell drilled to slip over the end of the burner pipe. This provides a shield to the flame, making it less subject to the effect of air currents generated by the rising heat. The spreader cap is a piece of bell-shaped metal perforated with small holes to cause the gas to be spread out as it escapes around the circumference of the pipe. Jet Size 1/16" in diameter.

with a standard fitting or a short piece of rubber tubing. The gas supply is turned on and off with gas cock, the most suitable one being threaded at both ends to receive a 15 cm pipe. At a point in the main line ahead of the gas cock, a small piece of wire gauge may be fitted into the main line to prevent the possibility of a flash back. The gauge will absorb and extinguish a flame should it occur below the burner.

d) Wood-burning Stove Adaption

Purpose - Domestic use

Description - A common wood burning stove by inserting a pipe and filling the stove with stones.



ADAPTATION OF WOOD-BURNING STOVES

To make the gas inlet jet, the burner pipe is to be closed with either bråss or lead between the gas cock and the air intake holes, after which a hole 1/16" in diameter is drilled through it to provide the jet. The diameter of this hole should be precise as the mixture of air and gas in the proper proportion depends on it. The burner is secured to the main line either

Air can be controlled with a piece of wood placed over the front hole, 0.5 wide, to serve as the air inlet hole.

Comments - Since the biogas and air mix properly in the drum mixing chamber before burning, combustion in this type of burner is very efficient.

e) Revolving Burner Model

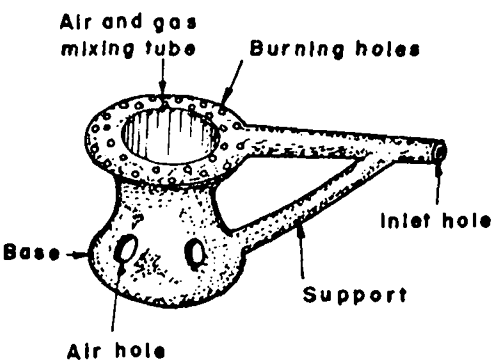
Description - This burner has a base and a cover, an air inlet hole at the centre and an enclosed ring for circulation of gas and air. To one side there is a gas and air inlet hole and the cover consists of burning holes. A mould has to be first made from clay and fine cinder powder. A circular base with a 2 cm diameter air hole in the centre is made. Around the air hole along the top, a circular groove 1 cm in diameter is made. Then, according to the size of the burner, a cover is made in which there is an air hole of the same size as that in the base. In the region surrounding the air hole a number of holes, 1 cm in diameter are drilled putting in 3 holes for every 2 cm. The cover is then fitted on the base and the interfaces sealed airtight. During burning, gas is ejected from the holes, with a continual supply of air from the hole in the centre.

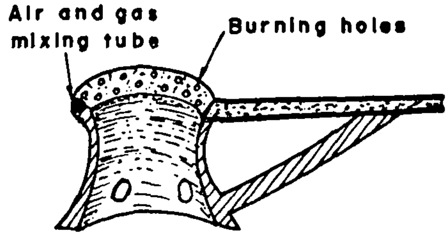
Comments - As there is a good supply of air, the flame is strong.

f) Long-arm Burner

Purpose - Domestic use. Both iron and aluminium pots can be used on this burner.

Description - This is an adaptation of the natural burner and is simple to construct.





(In cross section)

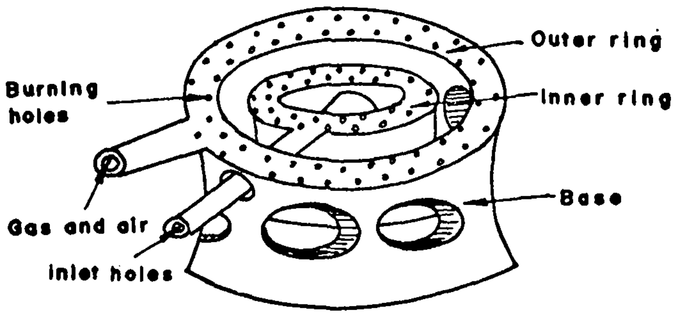
LONG-ARM BURNER

Comments - It gives a strong flame.

g) Double-ringed Burner

Purpose - Domestic; best suited for iron frying pans.

Description - It is similar to long-handled burners, but the inner ring is slightly smaller and a little lower than the outer ring.

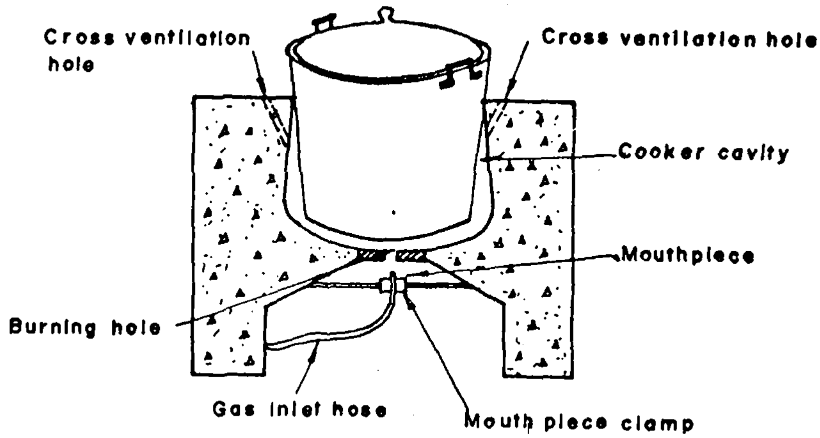


DOUBLE-RINGED BURNER

h) Biogas Stove with Built-in Cooking Vessel

Purpose - Domestic use.

Description - The gas is led directly into the cooker with the gas jet pointing directly at the bottom of the iron or aluminium saucepan. The mounthpiece is inserted through a hole in the bottom of the stove cavity which also lets in a suitable amount of air for mixing and burning.



BIOGAS STOVE

A certain distance between the mouthpiece and the hole in the bottom of the stove must be maintained to achieve a proper mixture of air and gas in the cooker and around the bottom of the saucepan during combustion.

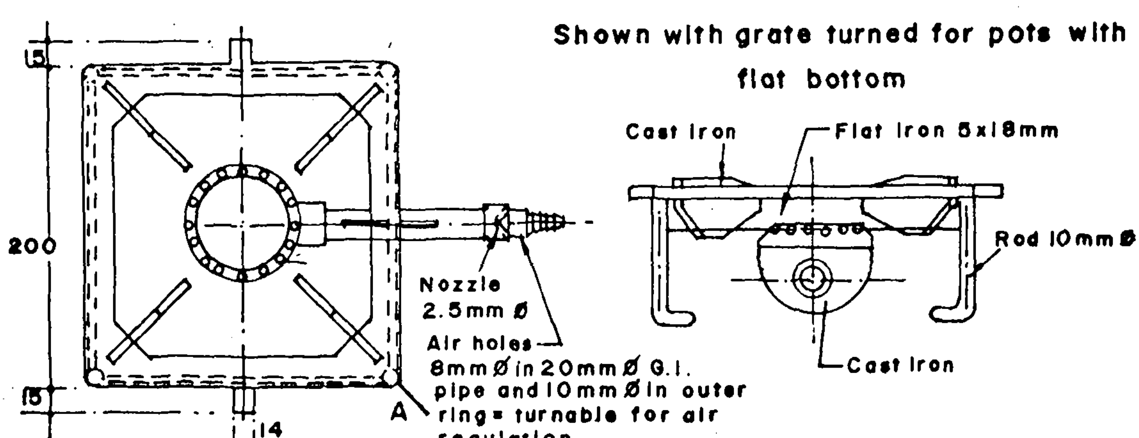
i) <u>Nepali Chula</u>

Purpose - Domestic use.

Description - It has a unique 'turn-over' support for flat or round-bottomed cooking pots. Cleaning is easy, by removing burner caps. The model is made of cast iron for long life and has a simple and easy to operate air adjuster.

Gas consumption - 0.45 m^3/hour

Comments - The air adjuster gives it the maximum gas burning efficiency.



NEPALY CHULA

9.3.2. Testing the Burner

Principle - Biogas burns even without a burner if a lighted match is held to the end of the pipe from where gas is escaping. However, for the flame to maintain itself, it is necessary to have a proper mixture of air and gas escaping at the tip of the burner. The air-gas mixing is accomplished at the bottom of the burner, when the gas mixes with the air as it passes the air inlet holes. With the burner fitted to the gas main line and with the gas cock open, the flame should maintain itself when a lighted match is applied and then drawn away.

Procedure - The burner is to be connected to the gas main and the gas cock kept open. If on the first trial of lighting a match the flame does not support itself, the gas cock should be closed slightly to reduce the volume of gas passing through. The column of gas if excessive, will be out of proportion with the proper volume of air and will thus blow the flame out, when the match is removed. The same problem arises if the number of air intake holes is out of proportion. Covering two or more air holes should determine if an excess of air intake is the problem. If so, the size of the gas inlet jet should be reduced with a few light taps of a hammer on the surface of the jet. Ideally, it would be desirable to have an insufficient volume of air intake in the beginning and then gradually increase the volume of air by drilling additional holes until an efficient flame is produced.

9.3.3. Insulation of Ovens and Stoves

As much of the heat produced from the burning of biogas is lost through convection and conduction, it is best to build stoves out of materials with low heat conductivity and which are fire-resistant. Placing the ring or jet ot some sort inside a stove may prevent any incompletely combusted gas/air mixture from escaping by keeping it in the stove cavity, to burn completely.

9.3.4. Operation

After connecting the stove to the gas tap, using a rubber tube, the air adjuster should be closed fully. A match should be lit and applied to the flame ports before the gas tap is opened fully. The cooking vessel should be put on it next. In case the flames are weak and long and rise over the vessel, the air adjuster should be opened to admit some air to the point when the burning gas will create a noise. The air adjuster should then be closed till the flames are about 2.5 cm - 3.0 cm high and the upper cone of the flame touches the cooking vessel for efficient burning.

9.3.5. Maintenance

The flame ports should be cleaned out when necessary. When a removable flame port cap is not fitted, the stove should be held upside down to prevent any dirt from getting inside and also to remove dirt which has fallen inside.

9.3.6 Economics

The amount of gas per person per day needed by different households varies according to the following factors:

- type of cooking (frying, boiling, baking, water heating)
- type of food cooked
- number of meals and snacks per day
- economy in fuel when cooking for a large number of people
- skill of cook in reducing gas flame size after a pot has been brought to the boil.

The average quantity of gas consumption for cooking meals per day per person is estimated to be 0.3 m^3.

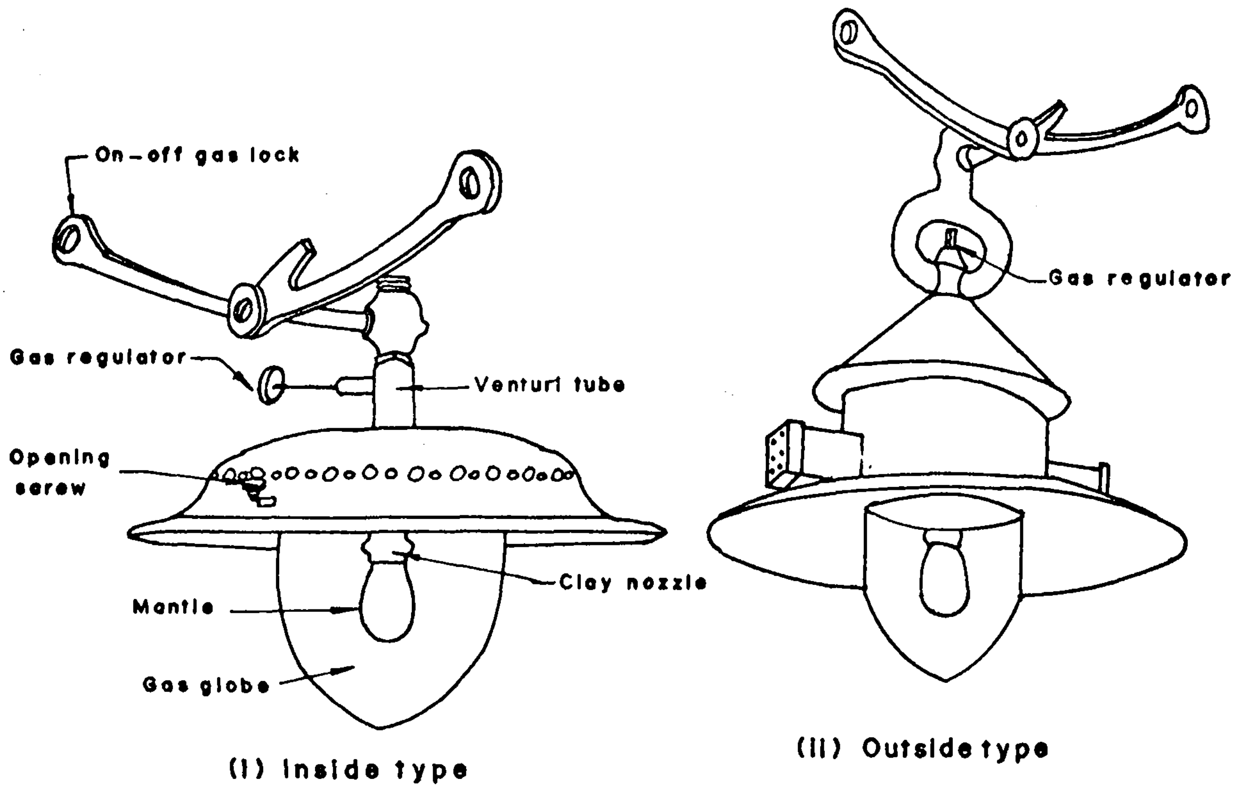
9.4 Biogas Lamps

Biogas lamps have the same characteristics as biogas stoves. A number of lamp models have been designed and are in use in different countries. Most of the biogas lamps are about 100 candle-powder and use 0.11 - 0.15 m^3 gas per hour.

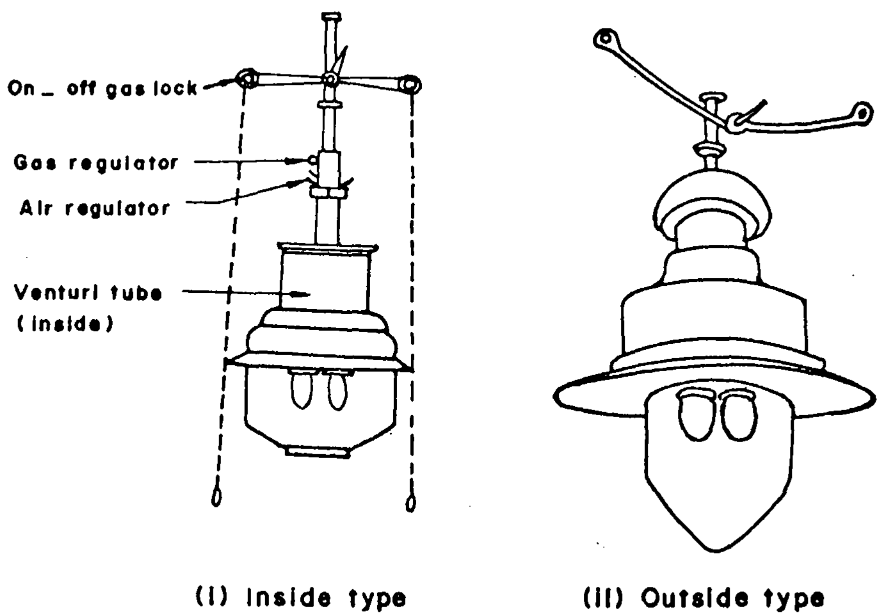
9.4.1 Lamp Models

i) Single Mantle Lamps

This was designed in India. There are two variations, with the mantle



SINGLE MANTLE LAMPS



DOUBLE MANTLE LAMPS

inside in one and outside in another. The inside model has a simple cover, Both the models are of about 100 candle-power.

- The mantles are soft and inexpensive.

ii) <u>Double-Mantle Model (India)</u>

This model has both the variations with the mantles inside and outside. The mantles in both the cases are preformed and expensive.

a) <u>Inside type:</u> This model has a simple cover. The model is available as a ceiling mounted model and a table model.

<u>Comments</u> - It has large hole in the base of the glass globe, which allows insects to fly inside and break the mantles.

b) <u>Outside type:</u>

- This model has no cover to protect it from wind and rain.

iii) <u>Chinese Model</u>

<u>Components</u> -

i) An aluminium tube about 10 cm long and 1.5 cm in diameter has four air holes of 0.3-0.4cm, a little below the top of the open tube.

ii) A gas diffuser held at the bottom of the aluminium tube, to which the mantle is attached.

iii) A disc reflector with a glass globe which fits at the bottom of the aluminium tube just above the diffuser.

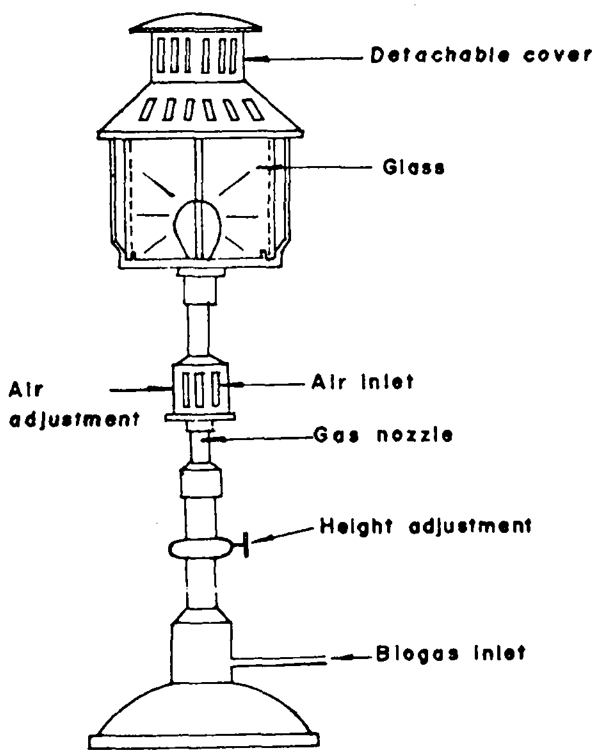
iv) A slim glass or plastic tube, 12 cm long and looking like a pipette. This tube slips into the aluminium tube and its top end is connected through a plastic pipe to the gas mains.

<u>Comments</u>

- This model is very simple to fabricate. A variation of this model in which the tube and the gas diffuser are made in one piece, from clay, is also available. The reflector is also made of clay. This clay biogas lamp is low-cost.

iv) <u>Table Lamps</u>

Biogas table lamps are best fitted halfway up a wall. Since the gas enters from below the gas hose is not damaged.



BIOGAS TABLE LAMP

v) <u>Mobile Lamps</u>

In the mobile lamp, the head is pointed upwards. The first time it is used, it must be turned upside down, the mantle allowed to set in its shape, and then turned over and used.

9.4.2. <u>Operation</u>

The lamp is opened and the clay nozzle (venturi) fitted. The mantle should be opened to form a hollow ball and tied to a venturi. The gas cock and regulator may be opened fully and the mantle lit and allowed to burn. The lamp may be closed once the mantle starts burning.

The lamp should be heated up till it makes a noise and the regulator adjusted till the mantle is at its brightest. It is not necessary to adjust the gas again until the mantle is changed.

The gas cock should be closed to trun off the lamp.

To relight the lamp, first the match should be lit and applied close to the mantle either through the hole in the bottom of the glass globe or by opening the reflector, and then the gas turned on. An explosion may occur if the sequence is reversed. After heating, the lamp gives a good steady flame.

When a new mantle is to be fitted, the clay nozzle should be removed and the venturi tube thoroughly cleaned out of any insects, cobwebs, carbon or dirt. The reflector and the gas globe should be washed with soap and water, whenever necessary, and left to dry completely before the lamp is lit as otherwise the glass may crack and the surface of the reflector may go dull.

9.4.3. Maintenance

Dirt, especially insects' nests in the venturi tube should be throughly cleaned, using a piece of cloth wrapped round a pencil or stick.

The needle in the gas regulator must be long, thin and have a fine point and should come down low enough to protrude through the jet and close it off.

- Biogas lamps can be justified only in unelectrified households. This is because lighting consumes gas inefficiently and regular attention is required to keep lamps burning well.

9.4.4 Economics

Economics - One mantle requires 0.11 to 0.15 m of gas per hour. This is approximately equivalent to a 60 watt electric light bulb.

9.5 Biogas Engines

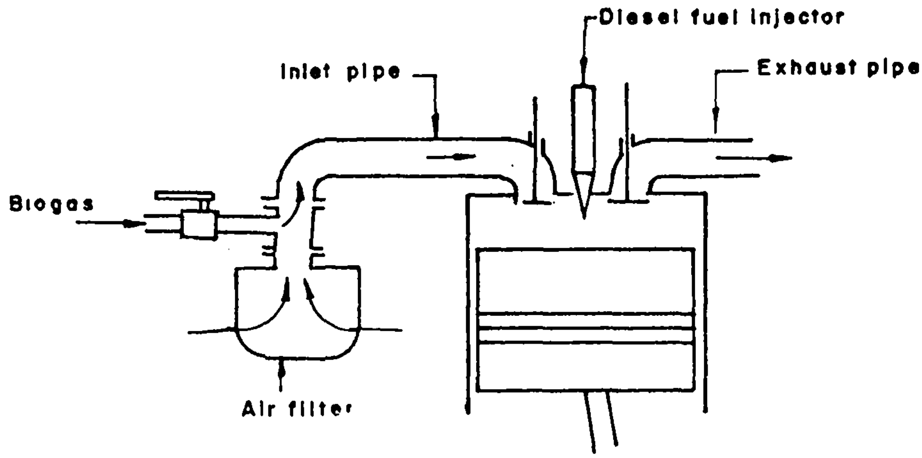
Biogas can be used as motive power for a variety of agro-industrial and other applications like water pumping, chaff cutting, threshing, washing, small-scale electricty generation, in flour mills, milk chilling units, etc. Biogas is being used either as the principal (85-90% of biogas) or as secondary fuel in most of the above operations. Use of biogas in engines necessitates minor to major engine modifications.

9.5.1 Engine Parameters Tested

Conversion of an existing engine to run on biogas should be preceded by the study of several parameters like engine performance on biogas, means of fuel induction/injection, smoothness of performance, material compatibility, emission characteristics of the engines, etc. The effects of biogas substitution in various proportions, engine performance at different speed and load conditions effect of air throttling etc., will also have to be studied.

9.5.2 Compression Ignition Engines

Existing CI engines require a minimum of 10-15% of diesel oil injected in the conventional manner for initiation and completion of combustion of the biogas air mixture inducted during the suction stroke. The performance characteristics of the engines having dual-fuel operation with biogas as the principal fuel (85-90%) biogas) and diesel oil introduced as the secondary fuel, are found to be similar to that obtained when the engine was operated with only diesel oil as the fuel. There is a reduction in the smoke number and nitric oxide for a higher percentage of biogas substitution; whereas the exhaust gas temperature and unburnt hydrocarbon content increase with the increase in biogas substitution. Heating of intake air could increase the rate of combustion which might improve the combustion process,



DIESEL ENGINES RUNNING ON DUAL FUEL

thereby increasing the thermal efficiency of the engine. Similarly, biogas gives a better performance if the engine compression ratio is increased. This, however, involves major engine modifications.

9.5.3. Spark Ignition Engines

Existing SI engines can be modified to operate entirely on biogas fuels. When so operated, the engine characteristics are similar in nature, to those obtained with gasoline operation of the engines.

There is however a substantial reduction in engine peak power and thermal efficiency with biogas operation.

Exhaust CO% increases in biogas energy substitution as also with throttling of the intake air. This may be due to incomplete combustion caused by reduction in avilable oxygen because of throttling of intake air. The rate of increase in percentage of CO is more at full load than at part load.

- The concentration of exhaust hydrocarbons increases with increse in biogas substitution. This may be due to the alterations in the stoichio metric and combustion characteristics brought about by increased proportion of biogas in the mixture undergoing combustion.

- There is a variation of smoke density with an increase in the percentage of energy contributed by biogas at diferent engine outputs. Actually, smoke density decreases with an increase in biogas energy substitution. Biogas combustion results in carbon and soot formation.

- Exhaust hydrocarbon concentration reduces with the leaning of mixture in the rich mixture zone. However, leaning of mixture beyond a certain point in the lean mixture zone causes a rapid increase in exhaust hydrocarbon concentrations. This is due to reduced flame velocity and incomplete combustion of ultra-lean mixtures, resulting in misfiring in extreme cases, with consequent rise in exhaust HC concentrations, etc.

- Use of biogas reduced exhaust HC concentrations by about more than 90%.

- Exhaust CO reduces as air to fuel ratio increases. This is due to the availability of abundant oxygen for the formation of CO_2 unlike with rich mixtures. Biogas substitution reduces exhaust CO concentration by about 90%.

CHAPTER - 10

SCRUBBING, STORAGE, TRANSPORTATION

10.1 Scrubbing

Biogas storage and transporation would be greatly facilitated if it is stripped of its impurities like CO_2 and H_2S. The removal of impurities from any gaseous mixture by physical, chemical or other methods is called scrubbing.

Biogas scrubbing is necessary, especially in large-size plants because

i) when biogas containing H_2 is used for direct combustion, it produces sulphur dioxide which will react with moisture to form a very strong acid. The sulphur dioxide discharge concentration in the case of large-size plants would be beyond the optimum permissible;

ii) if natural gas pipeline systems are to be used for transporting the biogas after scrubbing, the hydrogen suplphide content in the gas must be reduced to a level of less than 0.006 gm/m^3;

iii) the carbon dioxide reacts with the moisture present in biogas to form a weak acid which will readily attack metals;

iv) the presence of CO_2 effects the flame temperature and speed of biogas utilisation devices;

v) since carbon dioxide does not liquify and tends to form a solid called Dry Ice upon compression, storage of biogas in medium pressure tanks would produce lumps of dry ice in the compressor.

10.1.1. Reagents

Removal of CO_2 and H_2S from biogas either selectively or both impurities simultaneously is achieved by bringing the biogas into contact with a reagent which will tie up the undesirable gases as a liquid or as a solid. Some of the reagents used for the removal of CO_2 and H_2S are given below :

Water is one of the solvents that can be used for scrubbing biogas. Both CO_2 and H_2S dissolve in water, especially at elevated pressures. This is a physical separation process and both the gases can be released from the liquid phase by reducing pressure. The water, thus, can be recirculated many times through the system. The amount of water required depends upon the operating pressure in the scrubber. However, after a length of time the water has to be replaced, as otherwise, CO_2 and traces of organics would form noxious sulphides and contaminate the water.

However, water is good for removing mainly CO_2 H_2S is not very soluble in water but its level can be reduced.

Organic Liquid Reagents like MEA (Monoethanolamine), DE (Diethenolamine) and TEA (Triethanolamine) have high capacity for physically absorbing CO_2 and H_2S. Besides the gases, this also mops up the moisture present in biogas. The use of these solvents relies on heating and hence a complex shipping equipment is required. Consequently their use needs high capital and operating costs. These solvents are therefore best suited for large size plants.

Zeolites (Molecular Sieves) are solid adsorbents in a granular form which adsorb a range of gases, including CO_2 and H_2S. Besides the gases, this also mops up the moisture present in the biogas. Zeolites can be regenerated by passing hot air over it.

Activated carbon is also another solid adsorbent but it selectively removes H_2S.

Similarly a solution of either Sodium Hydroxide or Calcium Hydroxide extracts CO_2 by producing sodium or calcium carbonate . A solution of several metal salts (except those of sodium and potassium) can be used to remove H_2S since they form insoluble sulphide with H_2S. Iron Hydroxide is another chemical reagent for extracting H_2S. By using solid iron hydroxide, iron sulphide is formed, which can be regenerated by blowing hot air through the system. However, care should be taken not to use too much air and heat while regenerating otherwise, the accumulated sulphur will burn, producing sulphur dioxide.

Iron filling (wire wool) itself can be used to remove H_2S from biogas. However, the iron sulphide thus formed cannot be regenerated.

10.1.2 Scrubbing Process

A number of physical and chemical processes can be used for removing CO from biogas. The absorption method, which involves the transfer of a substance from the gaseous to the liquid phase is the most commonly used one. Absorbed materials physically dissolved in the solvent are suited for gas containing low concentration of H_2S in the presence of substantial concentration of H_2S.

The dehydration process is employed for removing water from biogas. Water is the most common, under viable impurity, for pipeline transmission. In addition to enhancing corrosion problems, water vapour can condense when the gas is cooled or compressed. The presence of moisture also reduces the heating value of the gas and adds to the transmission loads of pipelines. Dehydration is accomplished by (1) absorption of hydrosopic liquids, (2) adsorption on activated solid desiccants, (3) condensation by compression and/or cooling.

10.1.3 Biogas scrubbers

Equipments for biogas scrubbing are based on one or other of the methods described above. Most of the scrubbers incorporate both scrubbing and compressing units in one. For instance, the Swiss Federal Research Station for Farm Management and Agricultural Engineering has a transportable lowcost gas cleaning and compressing unit.

The scrubbers are however, mostly used in advanced countries. As it stands today, only a handful of agencies have taken up the manufacture of such equipments even in advanced nations.

10.1.4 Cost

Cost estimates for biogas scrubbing systems are determined by parameters like total net operating cost, total capital requirement, working capital, annual gas production, unit gas cost, etc. The scrubbing systems, are, however, found to be economic only in the case of large-size plants where biogas is put to varied uses. Scaling down of the system has to be done only after ascertaining the need and economic feasibility.

10.2 Storage

Purified biogas can be stored in bottles after liquifaction. However, unlike the commercially available bottled gas, liquifying methane is difficult. While butane and propane liquify at about 18 kgf/cm^2, methane can be liquified at a temperature and pressure of 162°C and 1500 kg/cm.. Consequently bottling liquified methane is not a practical proposition.

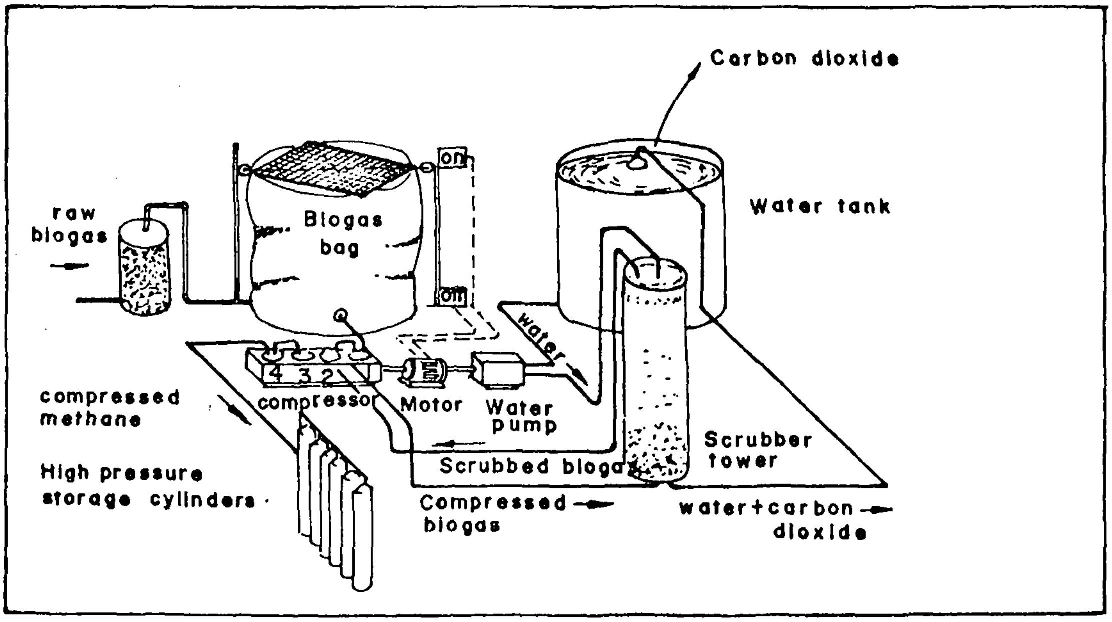
However, methane can be filled in cylinders of different temperatures and pressures. The volume of the cylinder required to store 28 m^3 (1,000 cu ft) of purified biogas at different temperatures and pressures is shown below. 28 m^3 of biogas can be stored in a 0.2 m^3 steel cylinder commonly available in the market for filling gases like CO_2, oxygen, etc. The 25 m gas thus stored would be sufficient for the cooking needs of a family of five persons for a period of about 30 days.

However, such cylinders are quite heavy and require at least two men fo lifting them. Also, for filling the gas a highly sophisticated arrangement is necessary for avoiding accidents. A regulator similar in use of oxygen and CO_2 is necessary for regulating the pressure of methane. As a result, bottling of biogas is not feasible except perhaps in situations where biogas is produced in large quantities.

Integrated units with facilities for scrubbing, compressing and storing biogas have been developed in certain developed countries. For instance, a water pressure scrubber coupled with a gas compressor and vehicle fuelling point is being promoted for uniform use in New Zealand.

Similarly, the biogas produced from poultry manure is being dried, scrubbed, compressed and stored at a pressure of 4 bars in a 200-litre steel tank in Belgium.

Biogas can be stored temporarily in polythene bags and balloons. This method is being experimented in India. One advantage of using such devices is that the biogas can be stored even without scrubb-



BIOGAS SCRUBBING DEVICE SCHEMATIC ILLUSTRATION ing. Moreover, this system works out to be less expensive and consequently, of more use for small-scale rural.

10.3 Transportation

The biogas coming from this gasholder can be taken to the use points either by collecting them in bottles or bags as mentioned above or piped through pipelines.

Piping of biogas can be either on galvanized iron (GI) pipes or plastic pipes. It is essential that the quantity and quality of biogas meets pipeline specifications. For instance, the hydrogen sulphide content of the gas should not exceed 0.006 g/m^3. Also, the biogas should be scrubbed off CO_2 and moisture. For removing moisture from the gas, moisture condensate traps could be attached to the pipe.

Pressure of biogas in the pipe is the most crucial factor to be considered while designing biogas distribution systems. This is all the more important in the case of small-scale systems when the biogas is piped direct from the gasholder to the use point. Generally, biogas is available at a guage pressure of about 10 cm of water column in conventional biogas plants. For efficient use in burners and lamps the optimum pressure should not be less than 7-8 cm of water column. When gas flows in a pipe there is a loss in its pressure due to friction. The pressure drop increases with the rate of flow and the distance between the biogas plant and the points of use. A properly designed pipeline is one which does not cause a pressure of drop of more than 2-3 cm of water column under any circumstance.

10.4 Application

Storage and transportation facilities are to be provided for only in the case of large-scale plants like community plants or those attached to institutions. Biogas produced from such large-sized plants are generally being put to diversified uses like agro-industrial operations and for power generation. Moreover, the use points in such cases tend to be situated away from the plant site. The extra biogas from family-size plants on the other hand, can be stored for a short period in the gasholder itself. The use points being mostly close-by family-size plants in developing countries does not require extra gas storage and transportation facilities.

10.5 Environmental Effects

Anaerobic fermentation is characterized by certain definite positive impacts, both immediate and long-term, on sanitational and environmental development. The immediate benefits result from the use of biogas as a fuel for cooking, lighting and/or engine fuel. Being a clean fuel it eliminates the discomfort of using smoking fuels in the kitchen and kerosene lamps in unelectrified houses of the third world.

The foremost among the long-term positive impact of the technology is the reduction in pollution and improvement in rural sanitation by using human and animal waste for biogas production. The anaerobic fermentation results in the destruction of pathogens. The concentration of pathogens, in the sludge, if present, has been found to be considerably less when compared to that of the input materials used. Fermentation at high temperature and longer retention time of the slurry give a higher pathogen kill ratio.

Furthermore, the fertilizer value of sludge has been found to be close to that of natural organic fertilizers. This, apart from reducing the over dependence of farmers on chemical fertilizers, ensures proper soil ecological balance.

CHAPTER - 11

UTILISATION OF SLUDGE

11.1 Fertiliser Characteristics

Approximately 70% of the total solids in the slurry can be expected to come out in the sludge; fermentation does not change the form and quantity of these elements. Depending upon the input material used the sludge contains elements like nitrogen, phosphorus, potassium, etc. as also several trace elements like boron, calcium, copper iron, magnesium, zinc, etc. Nitrogen is chiefly in the form of ammonium, which is less apt to leach away and is more suited to get fixed to exchange particles. The basic nutrient contents of sludge an shown chapter 18.

11.2 Uses

a) As Fertiliser

As already mentined, the sludge can be used as organic fertiliser. Generally, it is applied either as it comes out from the digester, or after dilution with irigation water. If the sludge is to be stored, it can be run into shallow pits and allowed to dry partially or fully in the sun. It is then dug out and stored in piles until it is time to be spread on the fields. The number of pits dug for drying and storing the sludge can be more than one such that by the time one pit is full, the sludge in the other is dry enough for carting. However, this method is rather a crude one and during the rainy season, protective roofing will have to be provided over the pits. Furthermore, some manurial value of the sludge may be lost by allowing it to dry.

In an alternate method, sludge is led by a channel to a filter bed with an opening at the opposite end of the sloping bottom. A compact layer of green or dry leaves is made in the filter bed. Water from the sludge filters down and flows out of the opening into a pit. This water can be reused for preparing fresh slurry. The semi-solid residue left on top of the bed has the consistency of dung and can be transported and stored in a pit for use when required.

b) As Enriched Organic Manure

The sludge, as it comes out of the plant, contains about 90% moisture and takes a long time to dry in the sun. Experiments conducted on this aspect have shown that the sludge could be absorbed in materials like dry broken leaves, sawdust, charcoal dust, etc., and then spread out to dry. The operation of soaking and drying can be repeated to yield twice the quantity of manure obtainable by drying the sludge alone. The nitrogen contents of the manure will depend on the original composition of the materials used but this can always be corrected to make the manures fit for use by enrichment.

The dried sludge by itself or by the above process may be enriched with fertiliser, nitrogen and, in addition, with phosphorous, if required, to obtain concentrated organo-mineral manures which could be applied in comparatively small quantities to act as a good plant growth stimulant. The enrichment can be carried out by taking 11 kg of urea and

31 kg of superphosphate and dissolving these in about 15 litres of water. This solution is then absorbed in 48 kg of dry low-grade manure mixed thoroughly and spread out in the sun to dry. The enriched manure would then contain at least 5% nitrogen and 5% phosphoric acid in addition to its original quantities of these plant nutrients.

c) As Compost

The sludge being full of bacteria which break down vegetable matter very well, is an excellent composting material.

Two or three pits of 80 cm depth are dug for the purpose. This allows the sludge to dry a bit and is not hazardous to animals which might walk into it.

The sludge is poured on top of the layer of straw, animal bedding, leaves or other vegetable matter. Alternative layers of vegetable matter and sludge are added until the pit is full. The pits must be large enough to hold all the compost until it can be put on the fields.

This compost, put on the fields in the normal manner, should be *ploughed in quickly*.

In places with a high water-table it is occasionally necessary to lift the compost out of the pits and put it on the ground to dry sufficiently for transporting it to the fields.

d) As Animal Feed

The dry sludge from the biogas plants looks and handles like humus and does not have the offensive smell of manure, neither does it attract flies. The anaerobic fermentation, moreover, retains the nutrients and enriches the sludge with B complex *vitamins, particularly vitamin* B12, which are synthesized during biogas production.

Solids are recovered from the sludge by allowing them to settle out in settling tanks by draining the liquid, and then dried, preferably under the sun or by artificial means in the absence of sun. However, solids should not be subjected to very high temperatures which can destroy the vitamin content. The dried lumpy solids are then ground and detoxified before mixing them with the other feed materials. In small operations where wet feeding is practised, the settled sludge may be fed with the slope without drying.

e) For Algae Production

After the solids are recovered from the sludge, the remaining liquid which contains nutrients and trace minerals, is considered to be a good promoter of algae.

Chlorella, a single-celled high protein (36-40% protein content) algae can be harvested with the liquid portion of the sludge in a shallow pond lined with concrete, metal or plastic material to avoid contamination and to make harvesting easier. Chlorella can be used in amounts up to 10% of animal feeds to replace soyabean soil meal for protein supplementation. Recently, spirullina is also being cultivated in the supernatant liquid.

CHAPTER - 12

PROMOTION CONSTRAINTS

12.1 The Dilemma In Promotion

The transfer and promotion of biogas technology in countries with widely varying agro-climatic, physio-geographic and socio-economic conditions calls for establishing its technical feasibility and social acceptance. While the feasibility of biogas technology for decentralized fuel and fertilizer production, pollution control, improvement in public health etc., has now been universally established, its acceptance in a given context is governed by an array of socio-economic, cultural and political forces operating outside the realm of the technology. Experiences in promoting the technology in developing countries has shown that, more often than not, an optimum balance has to be struck between these two interdependent yet near-diverging parameters. This can be brought about by assessing the social relevance of the technology in terms of its direct and indirect costs and benefits and chalking out popularisation plans accordingly.

12.2 Technical Constraints

Despite extensive research efforts, certain inherent characteristics and problems of technology are found to inhibit its promotion in the developing countries.

Most of these problems can be solved by systematic and need-based research and hence demand special consideration in respect of technology diffusion studies.

a) Non-availability of Construction Materials

Conventionally, building materials like bricks, cement, concrete, mild steel, etc., are being used for biogas plant construction. Plants made of materials like clay, neoprene bag, red mud plastic, etc., are also in operation. Recently the possibility of using PVC, ferro-cement, LDPE, HDPE, FRP, etc., in plant construction is being studied.

The existing plant construction materials generally pose several problems. For instance, some of the materials are either beyond the means of an average farmer or are in short supply in certain countries. For instance, mild steel, generally used for gasholder construction in some of the flexible gasholder models is an expensive commodity in many of the developing countries. Similarly, good quality kiln burnt brick is costly and scarce in certain situations.

Proper care and maintenance of certain materials require additional financial investment and/or labour from the part of the beneficiaries. The mild steel gasholders for instance, gets corroded fast and hence have to be repainted periodically. Materials like ferro-cement, on the other hand, require proper time for curing and plastering before start-up. Materials like LDPE, neoprene rubber bags, etc., are best used in underground plants only, otherwise exposure to ultra-voilet rays would destroy them.

b) Short Supply of Input Materials

Biogas technology claims to utilise any organic waste material for fuel and fertiliser production. In actual practice, however, only two types of wastes are being used as input material cattle dung, including piggery waste and a few agricultural crop residues. The rural economy of developing countries generally exhibits a high concentration of both livestock waste and cultivable land with a few minority. Also majority of the households possess only one or two herds of cattle. As a consequence, many of the rural households cannot ensure a steady supply of cattle dung necessary even for the smallest size biogas plant. Furthermore, the gas produced from such small-size plants can hardly satisfy the cooking energy requirements of the household. Biogas technology hence ceases to be a viable proposition for many of the rural households.

c) Production Not Optimised

Installation of a biogas plant does not always guarantee sustained biogas production. The irregularities in biogas generation are associated with the lack of optimum conditions, especially temperature and pH, prevailing inside the digester.

Gas production can be maximised either by providing optimum conditions for fermentation or by using certain additives. Slurry temperature can be maintained by methods like composting or plant insulation with rice husk, rice straw or by solar plant heating, etc. However, such methods for increasing slurry temperature are often introduced as attachments to existing plants and the cases where the rural beneficiaries are not generally inclined towards such extra fittings since they cannot afford them. Consequently, the gas production rate tends to decrease in the cold weather.

Inhibition of biogas release to the gasholder due to scum formation on top of standing slurry is another crucial factor in the success of biogas plants. More studies on the optimum levels of slurry mixing required for maximum digestion rate, optimisation of slurry mixing to varying loading rates, etc., are to be conducted to decide optimum conditions for the prevention/breaking of the scum.

d) Difficulties in Using Biogas

Efficient use of the biogas generated necessitates its cleaning, storage, transportation and, if warranted, conversion to other forms of energy. Various methods have been deviced for scrubbing the biogas off gases like CO, H_2S, etc. Even though a cleaning biogas would facilitate its compressing and bottling for storage and transportation, these activities are not economic in the context of small-scale family-size plants in developing countries. Low-cost, simple scrubbing devices, suitable for small-scale use, have not been deviced so far.

Non-availability of appropriate and efficient designs of utilisation devices like biogas stoves and lamps also pose major cosntraints in the popularisation of the technology. In addition, conversion of biogas to electricity is not economic and feasible especially so for a small-size plant.

12.3 Environmental Constraints

Several characteristics of the socio-economic and religious enviroment in which the technology operates are found to influence its progress. For instance, certain agro-cliamtic and physico-geographic conditions of a region might affect the variety and intensity of the benefits of its products. Similarly, certain social and religious beliefs can adversely affect the adoption of the technology in a specific context. In other words, notwithstanding the theoretical potential of the technology, the actual benefits that can be derived considerably on the environment in which it functions.

The likely impact of biogas technology on certain aspects of society are given below with a view to indicate some of the environmental factors operating against its popularisation.

a) Psychological Barriers

The prevailing social habits and prejudices of a community can adversely affect biogas promotion. For instance, the use of piggery waste may not be acceptable to members of a community or religion. Similarly, a lot of resistance is being shown to the use of human excreta for biogas production. Also, certain changes in cooking systems and food habits likely to be introduced by the use of biogas for cooking may not be welcome for some of the villagers.

b) Adverse effect on Lower Strata of Society.

One of the significant contributions of the technology is its claim of improving the lot of the rural poor by providing them with a low-cost but efficient source of fuel. The validity of the above claim in certain situations is questionable. For instance, it can have a negative impact on the availability of fuelwood and cow dung and the two popular domestic fuel sources in the rural areas. Due to the high investment cost of biogas plants, the households that can afford a biogas plant might, in most cases, also be the owners of the cultivable land and cattle heads. With the use of cattle dung by the households for biogas production, there is likely to be a more intensive dung collection process and thus the dung traditionally available free to the poor households is stopped. This might have serious repercussions on the rural poor since substantial portion of their fuel requirements are currently met by cattle dung. Concurrent to the decrease in availability of cattle dung, the demand for firewood might increase.

c) Positive Impact on Ecological Balance Unlikely.

It has been observed that in certain developing countries deforestation is caused primarily by the pressing need for more agricultural land to feed an expanding population, and an increasing demand for forest products rather than by use of firewood in the rural domestic sector. Similarly, much of the soil erosion caused by cutting trees is the result of commercial lumber operations of the Government and industry which indulge in thoughtless clearance of large areas. These factors indicate that biogas technology will have no significant role in the prevention of deforestation and restoration of ecological balance.

On the contrary, the technology might aggravate deforestation by depriving the poor people of cattledung.

d) Time-Saving Not Appreciative

Biogas technology is supposed to eliminate the drudgery of collecting firewood, preparing dung cakes or other similar time-consuming operations. However, in actual village situations where unemployment is still prevalent, people do have much free time for such operattion. In addition, when conventional fuels are available in plenty with no immediate financial investment, the benefit derived from time-saving may not be appreciated by the prospective beneficiaries.

e) Adverse Effect on Health and Hygiene

Due to the pathogen die-off during anaerobic fermentation, biogas technology is considered to be an efficient way of rural sanitation and public health improvement. However, some portion of the pathogens are removed from the digester along with the sludge, either by their floating to the surface of the slurry where the ova adhere to the scum or by setting at the bottom, especially in the case of plants with no stirrers and with the inlet connected to the middle portion of the digester. The short retention time provided in certain plant models also left some pathogens go along with the sludge. This raises problems in sludge handling in rural environments.

CHAPTER - 13

SOCIAL COST BENEFIT ANALYSIS

In the wake of the promotional constraints discussed in the foregoing sections, application of biogas technology calls for ascertaining its social relevance in the context of a nation/region/state. The relevance and viability of the technology in a given context can be ascertained with the help of cost benefit studies.

13.1 Objectives

A social cost-benefit analysis is intended to appraise a project from the viewpoint of all relevant objectives as defined implicitly or explicitly, by a system of weighing or shadow pricing for each objective, to produce a measure of the project/technology's desirability. In other words, a social cost benefit analysis gives a single Internal Rate of Return (IRR) or Net Present Value (NPV) at shadow prices. This involves mainly five stages:

a) Calculation of the financial profitability of the technology at market prices. This is the discounted cash-flow analysis of the Rate of Return of the resources involved in the technology, valued at market prices. This process establishes the commercial viability of the technology in terms of the capital cost of the plant, utilisation devices and equipments, operating cost of the plant and its devices, and the quantity and value of the biogas and sludge produced.

b) Shadow pricing of resources to obtain net benefit at economic prices. Here the market prices for the inputs and outputs are replaced by shadow prices based on opportunity costs or economic prices. The parameters for consideration have included the cost of alternate uses of the input materials (e.g., the use of cattle dung as dung cake or as fertiliser) used, and the energy saved from the use of the output (for instance: energy saved from reduced kerosene/firewood consumption by biogas.)

c) Adjustment of the project's impact on savings and investment. Here the net effect of the project on total savings for the village (by the use of biogas and sludge) and therefore by assumption, on investment, is quantified and revalued by the shadow prices of investment. Savings derived directly from operation would include reduced fuel and fertilizer consumption expenditures and any multiplier effect stemming from the alternative use of saved capital.

d) Adjustment of the project's impact on income distribution. In this stage, the income flows arising from the project are identified and income weights or shadow prices are placed on the income going to different groups. The differences between the value of income flows in money terms and their value in shadow prices is the

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December 4, 1985.

We are pleased to send you a copy of our publication entitled "Biogas Technology: An Information Package." This document gives packaged information on the various aspects of biogas technology development ranging from research to diffusion and sustained use. As such, the information package is intended to be a guide to anybody concerned with biogas technology as a viable energy alternative.

The preparation of the information package has been facilitated to a large extent, by the cooperation and assistance rendered by you by way of information materials, suggestions and comments. We are grateful to you for the same and we look forward to your continued cooperation.

In this connection, we are glad to announce that we are presently reorienting and strengthening our Energy Information User Network, with a view to facilitating information transfer among the various users of energy information. We are glad to invite you to be a member of the Network. A copy of the Membership Form is enclosed for your convenience. The Biogas Technology Information Package comes to you with the compliments of the Energy Information User Network.

Looking forward to your cooperation,

Yours sincerely,

N. K. Gopalakrishnan
Chief

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net social gain or loss resulting from the effect of the project on the distribution of income. The impact of biogas on the distribution of income of the village generally varies according to income, cattle and land ownership.

e) Modification and adoption of the technology and production of goods and services the social values of which are lower or higher than their economic values.

Social cost benefit analysis thus gives a near approximation of the actual impact of biogas technology on society. It permits a single measure of the desirability of the technology in a given context, by a system of weighing or shadow pricing of each of the objectives of the technology. Shadow prices of the outputs of biogas technology (i.e. biogas and sludge) will be based on either opportunity costs (i.e. resources saved elsewhere as a result of their production) or, if they represent a net addition to goods available, on what the beneficiaries are willing to pay for them.

13.2 Parameters Used

In a given context, the social cost benefit analysis of biogas technology is usually based on several variables. They are listed below:

1) Total biomass available per annum. This should include all the biomass resources intended to be used as inputs and be corrected for handling losses and system down-time (close-down of the plant for repair/maintenance).

2) Total biomass available for biogas production.

3) Cost of the digester, gasholder and other plant parts.

4) Cost of all accessories, connections, electrical wiring (if used for lighting) shutters, engines, cost of biogas engines, biogas burners/lamps, etc.

5) Cost of distribution pipeline for the supply of cooking gas (in the case of community plants).

6) Labour cost (for plant construction and operation).

7) Diesel required for pump operation per annum (litres/hr /BHP) x horsepower x duration/day x (365 days minus system down-time).

8) Diesel required for running other engines (calculated in the same way as given above).

9) Lubricating oil required per annum for the machines.

10) Lubricating oil required per annum for lighting.

11) Total annual cost of lubricating oil.

12) Material cost, for other small industrial applications of biogas if any.

13) Gas yield/kg of fresh biomass.

14) Gas required for cooking per annum.

15) Gas required for electric lighting per annum.

16) Gas required for pumping water.

17) Gas required for other applications.

18) Marginal increase in agricultural income per annum due to nutrient and humus content of sludge as a function of total quantity of organic material digested.

19) Economic life of the system.

20) Period during which the loan will be utilised.

21) Unit price of diesel fuel.

22) Unit price of surplus biogas sold as diesel.

23) Unit price of surplus biogas sold as electricity.

24) Unit price of fuelwood.

25) Unit price of lubricating oil.

26) Revenue from commercial operations, if any (annual sale of industrial products, etc.).

27) Interest rate of loan.

Note: All these parameters may not be very relevant in a particular given context and hence a selection of the most appropriate parameters may be necessary for any meaningful socio-economic analysis.

13.3 Ultimate Social Benefit

Analysis of the above variables at both market and shadow prices helps to establish the desirability or otherwise of biogas technology in a given context. The ultimate social benefit of the technology is a function of parameters such as

- its impact on saving and investment in the area;
- its impact on income distribution;
- the net present value of the technology;
- the ability of the system for pay-back, etc.

Cost-benefit analysis of both family and community-size plants are being done in India and other developing countries. The operational variables studied include:

- financial cash flow or economic net benefit stream
- net present value (NPV) or discounted net benefits
- Internal Rate of Returns (IRR)
- the pay-back period or capital or benefit-cost ratio (PV/K)

Many of the studies indicate that biogas systems are economical when they have an adequate cash flow. There seems to be a greater chance of economic viability with larger systems, especially those that can use the products in an industry and provide additional energy. There seems to be an economy of scale in the case of large-size family plants also. However, efforts towards reducing plants costs do not seem to be justifiable since the effect of cutting plant costs in large-size plants is only marginal.

Studies on the broader national costs and benefits of biogas technology have indicated its positive impact on the fuel/fertiliser situation of developing countries,irrespective of the private costs and benefits for its beneficiaries. This points to the fact that promotion programmes are to be streamlined to strike balance between the private feasibility of the individual beneficiary and national feasibility.

13.4 Limitations in Analysis

However, an ideal social cost-benefit analysis of biogas technology is beset with a number of methodological problems. The first and foremost of these problems is the non-availability and/or difficulty of quantifying several indirect or secondary benefits accruing from the technology. For instance, the quantification of the following benefits is difficult if not impossible:

- labour freed from gathering firewood
- reduction in the rate of eye and lung diseases among rural women
- environmental improvement

- improved quality and quantity of food consumed, consequent to increased crop production
- increased sense of confidence and self-reliance that a successful biogas system might instill in villagers
- better lighting on education
- more leisure, etc.

Furthermore, several technical data on the inputs and outputs of the technology are yet to be standardized. To illustrate data on the quality and quantity of biogas and or sludge produced and the properties of sludge when compared to farmyard manure are yet to be tested and confirmed. As a result, any calculation on the basis of such estimates remains merely a 'second best' assumption in the absence of accurate and properly quantified scientific information.

Another problem is related to the decentralized operation ot the technology. In the class of a family-size biogas plant, the input-output parameters will depend largely on the kind of food given to the cattlehead, their age, size and general health; whether any agricultural or plant wastes are used; the handling practices of input materials and sludge; and the operating conditions and practices followed by the plant owner. The prediction of supply response factors in such uncontrolled decentralized operations is generally difficult.

Consequently, the cost-benefit analysis of ideal experimental conditions often tends to be far away from the actual field condition.

Similarly, pricing of both inputs and outputs poses problems. In the case of financial analysis, for instance, the domestic market prices are to be considered. Domestic market prices of biogas and sludge should consider the likely impact of the product on the prices, if any, and the likely future impact on price improvements. The economic analysis on the other hand, is concerned with the set of prices which reflect the 'net efficiency' benefits to the nation. The net efficiency measure is associated with contribution of the technology to foreign exchange earnings. Moreover, in the developing countries at least, there are no organized and stable markets for the major inputs or outputs. Mostly, inputs and outputs like cowdung, plant waste, manure and cooking fuel are obtained at zero private cost. Thus the perceived opportunity cost of the materials may be zero for individual beneficiaries, but at the national level, it could be substantial. Also, market prices are affected by the performance of the larger economy: inflation, material availability, infrastructure performance, government price setting etc. Shadow price calculation also does not alter the fact that benefits and costs occur within the prevailing economic context.

CHAPTER - 14

DEVELOPMENT PLANNING AND IMPLEMENTAITON

Recognising the importance of biogas plants in the context of a developing economy and the significance of government support in the promotion of biogas technology, long-term programmes are required at national, regional and global levels for the integrated development and promotion of the technology. Biogas technology offers multiple use of its products and the dominant motivations for the adoption of the technology vary between nations. Hence the task of recognizing the motivating factors and drafting viable programmes for its promotion falls on the respective national governments. Such national efforts are however, not to the exclusions of long-term, collaborative efforts among nations offering commonalities of approach in terms of input material availability, construction materials, socio-economic and religious characteristics, etc.

14.1 Policy Formulation

Large-scale adoption of biogas technology can only be succesful with appropriate support from the government. Hence a sound and realistic policy for the purpose should take into consideration the following issues:

- short -and long-term energy demands in rural areas;
- mechanization of farming practices, rural electrification, etc;
- socio-economic and technical constraints of biogas technology in rural application;
- public health roles of biogas technology; and
- government's role in the promotion of the technology.

The policy should identify and define:

- felt needs of fuel and fertilizer
- priorty assigned to biogas technology
- targets attainable over the plan period
- incentives for capital investment
- anticipated benefits and impact of the programme

14.2 Development Planning

Biogas technology development planning involves outlining, organising and co-ordinating the research, development and promotion activities of the technology within a physico-geographic or political area. The development plan should be based on a feasibility study of the technology in the area in terms of its existing potential, present and likely future demand for the technology, investment and cost indices, likely response of the people to the technology, etc. In more specific terms the development plan should consider the theoritical potential of the technology, resource availability of the region (human resources/feedstock material) construction materials); assumed rate of acceptance; infrastructural facilities for the development and diffusion (R&D facilities/technical know-how/ human, material and financial facilities for diffusion) and above all, the financial resources required for the realisation of the programmes and the sources and guidelines for appropriation of the amount for development activities.

For convenience and as a test does for the viability of the project, there could be a short-term development plan. However, the overall long-term development plan would, most likely, be a phased-out one in developing countries. Each phase of development shall decide upon the maximum and minimum number of biogas plants to be set up, rate of acceptance by the people, plant model to be propagated; economic strata of society among which the technology has to be introduced; and facilities like R&D laboratories training institutes, plant fabrication units, financial assistance, etc. to be provided.

The National Biogas Development Plan gives the development policies and strategies for biogas production for the nation, and formulates time-bound action programmes. It is better to make the national biogas development plan a part of the integrated rural development programme of the country.

The plan should provide for/facilitate involvement of rural and local governmnets, institutions and other statutory bodies in the implementation of the programme. In addition, the national plan should take care to develop and/or strengthen grassroot level agencies for undertaking specific tasks relevant to the programme. This is besides ensuring a steady supply of financial assistance for the programme till such time that it takes off. The national plan should identify the organisational set-up necessary for programme implementation. In addition to the coordination of development activities, the function of the national agency includes collaboration and cooperation with international agencies involved in biogas promotion.

The regional agency is generally concerned with the planning and implementation of biogas development programmes for the region, within the framework of the national development plan. It serves as the nodal point for the national coordinating unit.

Microlevel units include a number of grassroot level agencies like local administrative units, development functionaries like extension workers, cooperative enterprises, voluntary agencies, community establishments, etc. These agencies are concerned with the actual popularisation and integration of the technology in the area. They mobilise support from the community for biogas adoption and seek measures for maximum community participation by alleviating the socio-cultural and religious barriers, if any, to its adoption. Further, these agencies are the channels for routing technical, financial and managerial assistance for the operation and maintenance of biogas plants from the R&D institutes and national agencies, to the beneficiaries. The grassroot level agencies go a long way in developing the infrastructural facilities for the region by providing guidance to private enterpreneurs and encouraging village youth to go in for training in biogas plant construction and management. In short, these microlevel agencies operate as the pace-setter of biogas technology in an area, by facilitating selective information flow from the R&D personnel managerss, decision-makers, etc., to the beneficiaries and vice versa.

14.3 Programme Implementation

Promoting research and development facilities and accelerating extension activities form the two cardinal areas of programme implementation. However, in the case of biogas technology, activities related to promoting community biogas plants and integrated biogas systems also loom large in importance because of their potential for large scale economic energy production.

(a) R&D Facilities

Biogas related R&D programmes are intended for deciding national and regional level research and development schemes oriented to the needs of the nation/region. Microlevel research and pilot programmes are required to render the technology appropriate in a specific context.

R&D programmes in biogas technology are two main categories: research efforts oriented towrads solving technical problems like defining the principles and processes involved, generation of scientific data regarding the various aspects of the technology, developing and standardising the plant parts and utilisation devices and other accessories, exploring new arena of use of productss, etc. Reserach efforts of this type are characterised by the generality and universality of their application.

The second category of research effort is mostly restricted to solving the problems posed or likely to be posed by the application of the technology in a specific agro-climatic or physico-geographic context. This includes ascertaining the role of the technology in the fuel/fertiliser scenario of a national region, cost-benefit analysis studies on the use of alternative and innovative materials for plant construction, possibility of using indigenous feedstock materials, trials on different plant sizes and use patterns of products, management and organizational patterns of community plants, feedback research, etc.

(b) Diffusion

Extension work can be initiated only after a systematic assesment of the potential and implication of the technology in the area has been made and the target beneficiaries and the plant model optimum size, appropriate feedstock have been decided upon. Probably the best method for biogas extension is to install one or two demonstration units in the area. The demonstration plant is best made true to the construction material and feedstock conditions of the village.

The grassroot level agencies involved in promoting the technology will have to encourage and assist the beneficiaries in the planning, construction, start-up and to a certain extent, the maintenance of biogas plants. The decision as to go in for only family-size plants or a few community plants, is to be based on the socio-economic characteristics of the village and the distribution of its households.

It is equally crucial for the extension programme to provide for adequate facilities for post-installation care and maintenance of plants. Methods for identifying and rectifying the sick units are to be deviced, in addition to providing the required expertise for plant maintenance. The expertise for repair and maintenance of plants as well as the facilities for fabrication of plants parts and utilistion devices are to be developed in the village itself. The grassroot level agencies can provide the guidance necessary for construction training, fabrication of equipments, getting the financial assistance for beneficiaries, etc.

(c) Community Plants

Community plants may be viable in the context of economies with widely varying income distribution and literacy patterns and where the individual plant ceases to be a viable proposition for households. Several studies on the biogas situation in India, for instance, shows that biogas is restricted to about 10-20% of the rural farmers who can raise the initial capital, who are sufficiently literate to be aware and to arrange for bank loans and subsidies, and who have the steady source of feedstock material. The majority of the rural population is constituted by marginal farmers with small land holdings and a few cattleheads and landless labourers. In such situations, the resources available to the marginal farmers mostly go un-utilized and their fuel and fertiliser requirements not met with. Community plants facilitate making optimum use of the resources of the region, besides providing a steady supply of fuel for multiple uses.

The case for community plants is further strengthened by the fact that there is a definite economy of scale in terms of plant construction cost, maintenance cost, space required etc.

As a result, countries like India, the Philippines, Thailand, Jamaica, etc., have initiated the setting up of community plants. In India the community plants are mostly meant for a few participating households or are attached to institutions. The Philippines and Thailand on the other hand, have large and/or medimum-scale plants attached to farms.

The success of community plants, especially those run by a few participating households, depends on formulating proper operational schemes. The schemes should take cognisance of the socio-economic and religious characteristics of the participating households and evolve proper norms for the daily collection of input materials and distribution of the products.

(d) Integrated Systems

Integrated biogas systems aim at the efficient generation of fuel and fertilizer production of protein via the growth of algae and fish in oxidation ponds, hygienic disposal of Sewage and other refuse, and a meaningful effort to keep the environment clean. The digester is the heart of the integrated biogas system because it treats the wastes sufficiently to allow the effluent to serve a useful purpose in the basins for algae and then in the fish ponds before it is absorbed in the soil by plants.

Addition of a photosynthetic step allows the minerals left by digestion to be incorporated into algae which can then be used as fodder, fish feed or fertilizer, or be returned to the digester process to increase energy production.

Such a system invloves low cash investments on a decentralised basis and is an apt example of "soft" technology that does not pollute or degrade the physical environment, and is appropriate for local skills and climatic conditions.

The most important feature of integrated biogas development is its viability for small and large systems. All the byproducts can be uttilised immediately and provide the farmer with the three elements (fuel, feed and fertilizer) essential to an integrated livestock-acquacutlture-agriculture-industry system of closed-cycle development. The potential for the integrated biogas system is unlimited for the whole of the developing world.

14.4 Financial Back-Up

Biogas development programmes are to be supported by substantial financial back-up till the programme takes off. The financial assistance criteria should be evolved after considering the *national benefits* of the technology and the differential capacity of the rural beneficiaries for repayment. The scheme for assistance would be effective only if a sliding scale of assistance is devised and the operational procedures for getting it kept to the minimum. A sliding scale of subsidies based on the size of the plant and the economic condition of the beneficiaries would help reach the small and marginal farmers also. Operational procedures are to be minimum as otherwise the realisation of the assistance tends to be complicated and delayed and in certain cases, the whole project might be dropped by the illiterate rural beneficiary.

A network of financial institutions incorporating government departments, banks, voluntary agencies, etc., is to be built in the country. These institutions would identify the beneficiaries eligible for financial assistance and provide advise and guidance for the realisation of the subsidy.

The norms for financial assistance can vary from one country to the other. The present practice is to give a portion of the initial cost of plant installation. However, there could be a provision for assistance towards purchasing biogas engines or other expensive devices also. Another significant aspect is the need to provide financial incentives to small-scale entrepreneurs who fabricate plant parts and utilisation devices.

The financial assistance offered is currently in the form of subsidies and loans from the national government. The subsidy/loan can be on a percentage basis (i.e. giving a definite % of the total cost) or fixed amount basis (i.e. depending on the category and size of the plant). The assistance offered is mostly recovered over a period of time, in which case the terms for recovery should be carefully planned in order not to have an adverse effect on beneficiaries from the lower economic strata.

The source of income and norms of allotment are to be decided upon at the national level in the case of non-recoverable investments.

Many of the developing countries are currently providing financial incentives for biogas plant installation, of both family-size and community plants. Financial assistance has been seen to have a positive effect on boosting biogas adoption in these countries.

14.5 Infrastructural Build-Up

The national plan should provide for the development of the required infrastructural facilities for the sustained operation of the technology. The infrastructural facilities include provision for developing skilled manpower for plant construction, repair and maintenance; encouraging entrepreneurial skills for the fabrication, transport and marketing of biogas plants parts, biogas stoves and lamps, biogas engines, processed fertilizer and animal-feed from sludge, etc. This is in addition to the development of grassroot level agencies for technology diffusion. Furthermore, proper information flow between the beneficiaries and innovation via the extension worker are also to be ensured.

14.6 International Cooperation

The interest in adopting biogas technology is on the increase among developing countries. Many of the nations seem to have decided to take the benefit of the experience, of the early adopters of the technology for formulating their biogas development plans. To illustrate, several

African countries are relying on the advances being made in Asia for formulating biogas development programmes. Modifications and improvements are made only if they are technologically warranted and socio-economically feasible in terms of the specific national considerations.

Similarly, there are attempts to identify commonalities of approach in terms of the feedstock and construction materials used, possible uses of products, etc., among nations with comparable agro-climatic and physio-geographic conditions. Several such cooperative ventures have already been initiated in Africa.

Likewise, plant models suited for the region are being demonstrated in Caribbean countries like Barbados, Jamaica,, St. Vincent, etc.

International cooperation in biogas promotion can include providing technical assistance, developing the required manpower, giving financial assistance as also information dissemination and feedback analysis. Technical cooperation however, is best if it is among nations of a region comparable in their agro-climatic and socio-economic characteristics.

CHAPTER - 15

GLOBAL SURVEY OF BIOGAS PROGRAMMES

Afghanistan

Biogas development has been initiated through a UNDP-supported biogas demonstration project. It has been proposed that demonstration plants be set up in each agro-ecological zone. Based on the experience obtained with the demonstration projects, extension programmes will be undertaken.

Argentina

A field extension programme is yet to be taken up. Prototypes of digesters are being developed at some institutions. The National Agricultural Technology Institute and the National University, Tucuman, are engaged in biogas technology research.

Australia

Australia with its substantial quantity of agricultural and forestry wastes and animal wealth has got tremendous potential for biogas production. There is an estimated potential of over 200 x 10^{15} joules per annum of cereal straw and a similar amount in forestry and other cellulosic wastes. Estimates indicate that there are approximately 2.5 million dairy cows, 2.5 million pigs and many millions of chicken. Domestic garbage and sewage could provide another 60 x 10^{15} and 4 x 10^{15} joules respectively per annum.

However, the main source of methane from organic wastes has been the municipal sewage plant. Plants for agricultural applications are generally smaller and less sophisticated than the sewage plant digesters. Small digesters for domestic or small-scale rural applications have also been designed along the lines of Taiwanese model and those of other Asian countries.

Attempts are being made for exploring the possibilities of other biomass sources. A study on the pretreatment and thermophilic anaerobic digestion of crop residues - chiefly barley straw, bagasse pith, rice hulls, pressed alfalfa, pressed grass fiber, filter paper etc. - are being conducted by the CSIRO. The Water Science Laboratories Pty. Ltd. are conducting investigations for the Australian Dairy Produce Board on the treatment of whey and casein washwater and potato wastes for biogas production.

Austria

Not much information in regard to biogas technology. A few plants based on the Darmstadt design were set up. However, unfortunately they did not function properly.

Bangladesh

Biogas technology has not yet been considered as a part of the national development programme. The promotional activities are mainly at project level.

Three research and development institutions (Bangladesh Agriculture University, Bangladesh Council for Scientific and Industrial Research, Bangladesh University of Engineering and Technology) have initiated three biogas research projects. With the technical support of the Bangladesh Agriculture University (BAU), four biogas plants have been installed by private individuals.

Various institutions/agencies like Agriculture Department, Bangladesh Small and Cottage Industries Corporation, Bangladesh Academy of Rural Development etc. have installed demonstration plants. The K.B.M. College Dinajpur has installed one demonstration plant with the technical support of BCSIR.

The Bangladesh Agriculture Research Institute (BARI) is also planning to install a few demonstration plants in selected locations.

Many of the plants so far set up are of KVIC design. However, experiments are being carried with fixed dome models. A comprehensive developmental plan, which would involve UNEP assistance, has been drawn up.

The Agriculture Credit Project Study Group of the Bangladesh Bank is studying the possibility of installation of a few biogas plants in selected locations. The Institute of Fuel Research and Development of BCSIR is now engaged in setting up demonstration plants in different areas and it also provides technical assistance to those willing to set up biogas plants.

Belgium

The International Association for Rural Development (AIDR) has been chiefly responsible for the developments in biogas technology in Belgium. Since 1978, a series of experimental and demonstration plants of various sizes have been installed by AIDR in Belgium. Belgium intends to use a variety of input materials like cattle dung, pig waste, poultry wastes etc. in biogas production. Optimum plant design specifications for the Belgian farmers are being developed by AIDR.

Bolivia

Bolivia is self-sufficient in most of the petroleum products and agricultural produce like sugar cane, rice, cotton etc. The livestock population includes over 4 million heads of cattle, 1.45 million pigs, 8.5 million poultry etc.

Biogas technology is comparatively new to Bolivia. The activities for biogas development are limited to those by the OLADE. As part of its Biogas Programme for Latin America and the Caribbean, OLADE is installing a few demonstration plants of the Chinese model, OLADE-Guatemala type and the Xochicalli-Mexico type in Bolivia. The Bolivian Biogas Development Programme will be formulated only after assessing the technical feasibility, economic viability and social acceptance of these demonstration plants.

Botswana

In Botswana there are more than 4 million cattle grazing over large areas. To provide the cattle with water, diesel pumps are used to pump water from boreholes. A project has started by RIIC (Rural Industries Innovation Center) to investigate whether it is possible to propel the engines with biogas produced from the cattle manure.

As the manure is available at the place where the biogas is needed, the need for transports is eliminated. The depth of an average borehole is 115 m. To run an engine for that hole it is estimated that the manure from 13% of the average number of cattle drinking the water will be needed.

Brazil

To reduce Brazil's dependence of imported petroleum, a National Biogas Programme was started in 1978 by Secretaria de Technologia, Ministerio das Minase Energia, Brasilia. The objectives of the project was to support the diffusion of biogas technology in the rural, agro-industrial and urban areas of Brazil.

In the rural sector the goal in 1981 was to have 50,000 operational rural biogas plants. In the agro-industrial sector 300 plants are planned in 1981, e.g. at distilleries and butcheries, and tanning industries. Sanitary landfills (landfills with household wastes, which produce biogas) are planned to be used in urban areas.

There are also some local rural biogas programmes sponsored by different organizations, for the dissemination of biogas technology and the construction of small biogas plants.

Burma

At present Burma is self-sufficient in petroleum and natural gas. Fuelwood and charcoal, the main sources of domestic fuel in rural areas, are also in relative abundance as the forest cover constitutes 57% of the total land area in the country. Annual production of fuelwood is estimated to be 14 million tonnes, and charcoal about 626,000 tonnes. Fuelwood resources are now, however, uniformly distributed. Due to lack of satisfactory transportation, deforestation has become quite serious in some fuelwood-deficient areas. Recognizing these problems and anticipating greater demand in the future due to population growth, steps are being taken in the country to find alternative sources of energy.

Biogas production from animal dung is one such alternative. The Central Research Organization has been experimenting with this technology for the last ten years. Recently, the Agricultural Mechanization Department of the Ministry of Agriculture and Forestry has taken the initiative in expanding the operation. A semi-industrial type biogas digester with the capacity to produce 51 cubic metres of gas daily was constructed in 1980 at the pig husbandry farm near Rangoon. This pilot activity was very successful in publicizing the use of biogas in the country. In 1981, a prototype digester was shown at the Union Day Exhibition. It attracted attention from both individual farmers and members of cooperatives. Six continuous floating-drum type digesters were constructed in that year on cooperative and meat-producing farms. In 1982, a floating-drum digester with the capacity to produce 17 cubic metres of gas daily was constructed for experimentation purposes at a quail farm in Rangoon. Stemming from this experience, 40 additional biogas plants are in the process of being constructed on quail farms in Model Village Number 1, near Rangoon, Furthermore, two digesters of fixed-dome and floating-drum types have been installed at the training centre of the Department of Veterinary and Animal Husbandry to provide gas in the residential areas of staff and trainees. The Agriculture Corporation has been experimenting with composting crop residues for the production of biogas and early results look encouraging.

The emphasis on biogas is further evidenced by the establishment of a project for biogas production and utilization under the Ministry of Agriculture and Forestry, in January 1983. The objectives are to carry out research, propagation and training activities. The project is expected to provide technical assistance in the construction of biogas plants in all parts of the country. So far, four different types of digester for domestic use have been constructed as part of the training programme. Forty-two government officers have been offered three weeks' training with the objective of extending the knowledge to rural areas.

Chile

Biogas technology is rather new in Chile. Campo Experimental is perhaps one institute where the potential of biogas technology is being studied upon. Even though sufficient interest in the technology has been generated in many farms in Chile, its popularisation is limited by the problems associated with the transporting the biogas produced. This is because the farmsteads in Chile are mostly situated away from the housing facilities and on-farm use of biogas does not justify its installation. Any programme for spreading the technology in Chile would therefore depend on the success of developing economic and efficient methods of transporting biogas over a few hundred meters.

China

Two major intensive campaigns during 1969 and 1976-78 resulted in the widespread use of biogas technology and construction of seven million plants in China. The majority of these plants are found in regions where climatic conditions are favourable, where input materials and supplies are satisfactory, and where fuelwood resources are scarce.

The bulk of the biogas plants installed so far are of the spherical or oval water-pressure dome type, with a few experimental ones of other kinds. It appears that farmers prefer a continuous rather than a batch process, mainly because raw materials which are available daily can be used thus providing a more continuous supply of gas. In the larger-scale experimental plants, the construction and testing preceded planning for utilization of the biogas. One explanation for this is the need to demonstrate the success of the digester before contemplating investment in major gas-using appliances/-machinery. The volume of gas produced for medium-sized plants could be much higher once the complete system for their production and utilization was developed.

The Chinese programme for biogas experimentation is extensive and well conceived, although it appears that some improvements can be made in communicating between users and researchers. Similarly, more coordination between research and development activities in the different provinces could be beneficial.

Measures for the popularization of bigas in China are impressive, as are the efforts to train people in construction and management of the plants.

The financing of biogas plants in China comes most frequently from three sources: (a) the farmers' own incomes, which in the rural areas, usually cover from 20 to 50% of the total cost; (b) the investment funds of the team, brigade or commune, which covers 20 to 50%; (c) Central Government funds in the form of subsidies, ranging from 30 to 40%. In other areas of China, the proportion covered by farmers was usually higher and the percentage of the Central Government lower than the figures indicated above. However, it still shows the need for substantial financial resources in addition to the basic investment farmers make out of their own incomes, over which they have full control.

However the number of operational plants have declined recently due to certain unavoidable problems requiring attention and research for solution. Based on the Chinese experience, the types of problems encountered when embarking on large-scale biogas programmes may be technical, social, economic or organisational. Technical problems related to household units are often related to:

- poor construction of individual digesters, frequently resulting in gas leakages;
- difficulties in maintaining and managing the digesters at reasonable levels of production;
- low gas productivity in the cold season;
- difficulties in emptying the digesters;
- difficulties in transporting large volumes of sludge to the fields because of its high water content.

Different policies on biogas appear to be evolving in different regions of China. The lack of success of past programmes in certain areas have made decision-makers in those areas reluctant to embark on new crash programmes. However practical biogas programmes should be pushed forward at maximum speed.

Colombia

Biogas offers health-related advantage for Colombia. Hundreds of Colombians are severely injured each year in home fires because many low-income families still cook on cheap stoves fueled by a low-grade but highly volatile gasoline, "cocinol". In time, the Betancur government plans to phase out the use of cocinol and to replace it with safer low-priced fuels, and biomass methane has been suggested as one possible substitute.

In a pioneer project, the Colombian Nuclear Affairs Institute (IAN) are investigating the feasibility of launching a large-scale biogas program in the central Colombian city of Neiva in the hope it will be possible to construct a garbage-to-energy plant producing methane gas for domestic consumption in the city.

Preliminary results of the Neiva pilot project are promising, according to the IAN Solar Energy Department. In the opinion of the institute's research workers, the distribution of methane to households should present no undue difficulties as, in at least some districts, existing natural gas network piping could be utilized.

Major biogas projects would require a constant flow of garbage and, to supply the needs of municipal biogas plants, city authorities would have to improve garbage collection practices.

The problem is likely to be financial rather than technical, as many observers wonder whether funds can be found for major biogas programs. The government is also pressing ahead with plans to extend the use of cheap Colombian natural gas, now being used in thousands of homes in the northern coastal region. It remains to be seen whether biogas can compete in cost with natural gas in Colombia.

Costa Rica

Research and development work is being undertaken at the Institute Technologico de Costa Rica. Biogas digesters developed by the Institute are being tested further.

Denmark

The Danish public authorities have concentrated their efforts in the development of biogas generation from farm wastes. It has been proposed that energy should be gained from wastes whenever feasible, in order to enhance the energy autonomy of large farms. When the farm wastes consists of moist matter (e.g., manure), fermentation to produce methane is the preferred process.

The Ministry of Trade is coordinating a 3-year program, which started in 1978, at the Institute of Technology in Taastrup, near Copenhagen. The program includes nine Danish Institutions and Organizations under the group-name "STUB" (Samarbejde on Teknologisk Udvikling of Biogasanlaeg). Carl Bro International A/S was appointed project coordinator. The program includes the construction of three demonstration digesters at the farms of some farmers motivated to investigate the process. They are: a single-step, completely-mixed plant of 270 m^3 volume; two single-step, completely -mixed plants of 180 m^3 each; two parallel displacement-type plants of 170m^3 each. Two pilot scale plants with capacities of 1 and 20 m^3 are located in the Research Station for Plants in Ascow (Jutland). The input is either cattle or piggerymanure. The parameters under study are: temperature of digestion, gas production rate heavy metal content of mixed liquor and sludge, pathogenkill, and field behavior of anaerobic sludge.

Besides these state-coordinated projects, the following projects have been undertaken. According to I.C.I. (Imperial Chemical Industries), a full-size plant for biogas production from yeast fermentation wastes has been constructed in Denmark. The Royal Danish Technical University conducts laboratory-scale experiments in two-stage digesters, aimed at optimizing volatile acid production. The Bioteknisk Institut at Kolding, has been conducting research on methane production from manure. A Danish company, Horlyck and Kongsted, is interested in marketing digesters for farm waste treatment. Three established biogas plants are further reported in operation: a 45m^3 continous biogas plant at a private farm at Stenderup in Bramming, a 90 m^3 batch plant at the farm at Skarrild in Herning, and a battery of five 80 m^3 batch digesters at Aby in Fyn.

Dominican Republic

Dominican Republic has an estimated wealth of 2.15 m cattle population, 250,000 pigs and 54,000 sheep, besides the agricultural crop residues for biogas generation. Activities in the area of biogas technology are carried out chiefly by the University of Santo Domingo under its Energy Programme. Emphasis is on the use of food leftovers like rice, beans etc. and agricultural left-overs like coffee pulp, industrial wastes like alcohol distillery slops etc. in biogas production.

Egypt

Since 1975 the NRC (National Research Council) has been interested in developing the biogas technology, and some uncoordinated attempts were made to do this. In 1978 a national biogas research and development programme was started at the Academy of Scientific Research and Technology (ASRT), financially supported by the USAID.

Socioeconomic surveys over typical Egyptian villages and study tours to India, China and Thailand were made. Two villages, one traditional and one newly planned, were selected for field demonstration.

R&D endeavours include: research on optimum conditions for digestion, on pathogen destruction-rate, and on the evaluation of fertilizer.

Three family-size digesters, Chinese rectangular and cylindrical models and a plug-flow digester model were constructed, operated and tested at the NRC.

As a part of the ASRT programme a digester was built in a rural village. In the village a family was carefully selected for the care of a demonstration plant. The selection was based on previous sociological surveys of the village. The impacts of the biogas plant of the members of the family was studied in different ways. The Egyptial biogas programme seems to take into account the sociological aspects of biogas implementation in a serious way.

Equador

Equador has today a supply of oil that covers the demands of the country. But the oil-resources are rapidly being depleted so there is a governmental interest in developing non conventional energy resources.

The existing biogas plant, more than 12 units, are built with financial support from GOE (Government of Equador) and with the volunteers from the PC/E (United States Peace Corps). By order of GOE, the USAID (United States Agency for International Development), made an assessment of the existing demonstration plants and proposed activities concerning a future biogas programme. The study showed that biogas can be implemented in Equador for producing energy from animal wastes, plant wastes and human wastes, at least for those families that have enough confined livestock. For those who don't have enough livestock, community digesters could be a solution. However, the extension of community digesters will depend on the biogas plant and the distribution of the gas.

A systematic evaluation must be made of existing and future demonstration plants. A public education and training programme is necessary to spread the biogas technology. The development of an implementation plan must be based upon the analysis of data from existing digestors, including economical and social analysis. A national plan should be developed by INE (Instituto National de Energia) and other institutes engaged in biogas.

Ethiopia

With the objective of improving the working conditions of women, research is carried out on biogas and the improvement of stoves at the Department of House Science and Technology, Awassa Junior Agricultural College.

Two digesters (one of Indian design and one of Chinese design) and three stoves have been constructed at the college.

The production of biogas and the development of improved stoves is hoped to save household fuels, human energy and time, and they will contribute to the forest conservation programme.

Federal Republic of Germany

There has been much interest in the development of biogas technology from 1945 onwards. Initial work on the generation of biogas through sewage treatment was taken up by Imhoff and Popel. Later, it was realized that the experience obtained with sewage sludge digestion was of little use when agricultural wastes were to be used for digestion. A number of institutions like the Technical University, Berlin, the Technical University, Darmstadt, the Institute for Soil Science and Agricultural Chemistry, Gottingen, Hohenheim University, Munchen University, the Technical University, Hanover, the Federal Research Institute for Agriculture, Volkenrode, and the Kuratorium fur Technik in der Landwirtschaft, Frankfurt, are engaged in research and development work. Many types of designs like "Darmstadt", "Berlin", and "Hanover" were evolved for small-scale application, 'Munchen', "Hohenhein" and "Untersontheim" were for medium-scale application and "Allerhop", for large-scale use. Most of the designs had some provision for heating the digester contents. All the designs except "Allerhop" proved to be very sophisticated. The designs were displayed from time to time for the information of the general public and farmers but did not generate much interest. In terms of energy production an anerobic digester was not an economical proposition especially on a small scale.

The large-scale "Allerhop" design was the most successful one and was produced as an effective way of processing manure in liquid form at minimum labour costs. Gas collection was considered a secondary objective. Around 50 digesters with an annual gas production capacity of 18,000-300,000 m^3 were reported to have been set up. In most cases, gas production is used only for heating the digesters and driving central motor pumps.

Fiji

The country with over 300 islands and a predominantly agricultural economy, possesses no known oil reserves. Fiji has a small but fast developing livestock industry with about 151,000 cattle, 39,000 horses, 55,000 goats, 23,000 pigs and 896,000 poultry. The warm and relatively wet climate also offers a good case for biogas systems.

Biogas development began around 1969 and currently 45 plants are in operation using chiefly pig waste as input. The gas generated is mostly used in simple ring type cooking burners and a few incandescent mantle lamps. Trials have been made in using the gas to fuel diesel engines and absorption type refrigerators. However none of the plants currently operating, generate sufficient gas to operater either for any length of time. Very little systematic use is made of the nutrient content of the sludge.

The major problems associated with biogas development in Fiji are the lack of sufficient quantity of input materials, high cost of plant construction and technical problems like faulty material and techniques of plant construction, blockage of inlet and outlet pipes etc.

Future developments in biogas technology in Fiji should concentrate on designing and developing plant models appropriate for the rural conditions and investigating methods of making maximum use of the biogas and sludge.

France

The Societe d'Etudes et de Gestion du Procede CETOM-METHANE in Lyon is marketing a system to digest domestic solid wastes. A 1 m^3 pilot-scale digester is in operation. In 1977 the Company published a well-documented brochure. Biomechanics Ltd., (U.K.) has been commissioned to construct a biogas plant in Bordeaux to treat starch-gluten wastes.

Many waste water treatment plants in France have been equipped with anerobic sludge digesters. A survey of these anaerobic sewage-sludge digesters has been made by the Ministry for Culture and Environment. One of the major plant is in operation at Acheres near Paris. Two companies, Degremont and the Omnium d'Assainissement are marketing sewage-sludge plants.

Use of spent-wine distillery wastes at the pilot scale plant has been studied in a joint venture by the I.N.R.A. (Instiut National de la Recherche Agronomique).

German Democratic Republic

Progress in biogas development have followed the developments in the Federal Republic of Germany. However, not many plants have been set up. At the University of Jena it was found that in thermophilic digestion, the hygienic properties of manure improve further, digestion is quicker and extra heating costs are compensated for better. In the 1950s the Technical University, Dresden, undertook research and development work on biogas technology, Various modifications of the Allerhop design were tried to assess their suitability. Cost reduction and gas storage studies were made. A gas storage system consisting of a gas sack made of cotton and rubber with pressure devices was developed. However, by the end of 1950s less emphasis was placed on the programme mainly owing to its having been found uneconomic.

Guatemala

Guatemala has been a central place for the biogas development in Latin America. In 1977, at the First National Seminar on Appropriate Technology, in Panachel, Guatemala, the Project Rede-bio was started. It coordinates seven groups working on the reutilization of bio-degradable wastes. They have built some experimental prototypes of the Chinese and Indian designs.

Also Anaerobic digesters for processing coffee pulp, sugarcane bagasse and sawdust have been evolved. The Mesoamerican Appropriate Technology Centre and the Central American Industrial Research and Technology Institute have developed prototypes for use on a commercial scale.

Guyana

Guyana is characterised by the presence of oil reserves, a variety of agricultural products, large areas of unimproved land in the coastal region for agriculture and a predominantly poultry-based livestock industry. It is one of the countries chosen by OLADE for its demonstration biogas plant projects. Demonstration plants of 3 models - a semi-continuous Chinese model, batch fed OLADE-Guatemala model and another semi-continuous Xochicalli-Mexico model - have been installed for assessment of techno-economic viability and performance evaluation based on which further plans for biogas development will be formulated.

Honduras

With over 2.2 m heads of cattle, 4.6 m poultry and an essentially agricultural economy, Honduras is perhaps one country favourable for biogas development programmes. However, the Honduras attempts in the area of biogas development are limited to the Biogas Demonstration Programme of the OLADE under which a few demonstration plants have been installed.

Hungary

Work on biogas technology started in Hungary in the year 1956 at the Institute of Heat Transfer at Budapest. In 1958, research and development work was taken up at the Agricultural University, Szekers, the Research Institute for Soil Science and Agro Chemistry, and the State Design Office of Civil Engineering. Many aspects, such as the fertilizer value of digested manure, optimum conditions for digestion and techno-economical feasibility of various designs, were investigated. However, not many of the anaerobic digesters set up in Hungary seem to be in operation.

India

Biogas history in India dates back to 1897, when one of the first biogas plant in the world was built at Matunga Homeless Lepers Asylum near Bombay. However it was not until the late 1930s that anaerobic digestion of manure attracted the interest of scientists and technicians. In 1960 the Gobar (cowdung) Gas Research Station was set up at Ajitmal, Uttar Pradesh, and in 1962, the KVIC started its Gobar Gas Research and Development Centre and included a biogas scheme in its rural development programme. KVIC has a network of technically competent persons to give advice on biogas implementation all over India.

In the 1960s work began at IARI (Indian Agricultural Research Institute) and NEERI (National Environmental Engineering Research Institute).

By the 1970s, biogas has been identified as one of the potential renewable sources of energy. Nearly 100,000 biogas plants have already been set up in India and a programme of setting up 400, 000 units during the Sixth Five-Year Plan period has been launched. The target fixed for 1982-83 was 75,000 gas plants. Total annual gas production from these plants is expected to be 1926 million m valued at Rs.1,458 million. In addition, humus and nitrogen rich manure produced annually from these plants would be of the order of 1,964 million tonnes valued at Rs.98.2 million.

In respect of gas plants to be set up with the financial assistance from banks, it has now been decided to release the subsidy to the banks in advance. The advance payment is hoped to reduce the incidence of interest on the beneficiaries and thus help expansion of biogas programme at a faster rate.

Community biogas programme in India is at the moment, in an experiment stage. Though the biogas technology is technically feasible, its economic viability, social acceptability, management system, etc., are yet to be examined for correct assessments.

The Commission for Additional Sources of Energy have initiated the programme of setting up experimental community biogas plants in the country under the All India Coordinated Biogas Project. Feasibility study, designing and execution of 12 community biogas plants in the country are in progress. Suitable local agencies would be identified to take over the projects and the management of the projects would be handed over to these agencies in a phased manner.

Biogas plant, especially the Indian type is still too expensive for the poor majority. It has also been shown that even if a digester were installed free of cost, the poorer people would not be able to operate it, due to lack of cattle dung, water, land to spread the fertilizer on, and lack of money and skills necessary for the maintenance. As a consequence lack of interest in the technology is to be expected.

Indonesia

Due to surplus of firewood, shortage of animal wastes and the opposition of the people to handling pig waste, biogas technology has not caught up momentum in Indonesia.

Moreover The Bandung Institute of Technology, its Bogor Biological Institute and other governmental institutions are engaged in research and development work. Efforts are being made to evolve an efficient model through suitable modification of existing Indonesian and Chinese designs.

Some demonstration units have been set up at places like Denpasar, Petung, Atuag, Bogor, Baruajak and Bali. The units are made of oil drums with floating gas holders. There is opposition to the use of pig dung as a feed stock by the Muslim population.

The Indonesian Board of Voluntary Services is promoting the biogas programme by putting on demonstrations at the village level to convince villagers and village leaders. The Bogor Biological Institute is also launching a biogas programme based on the use of agricultural wastes as a feedstock.

In 1981 the FAO/TCP biogas project was initiated in Indonesia with the objective of setting up a few demonstration units, providing training and preparing a comprehensive programme for incorporation of biogas technology in the integrated rural development programme. The Government is planning to formulate a national biogas development programme, with Bali as the focal development centre.

Iran

The Centre for Endogenous Development Studies is engaged in propagating a biogas development programme in western Iran. Trials are being carried out at Niazabad with KVIC-design plants.

Israel

Recent energy shortage in israel has increased the interest in methods of energy conservation and exploitation of new and renewable sources of energy in Israel. Biogas production from various agricultural wastes like cattle manure, cotton stalks, straw etc. is one of the alternatives considered for the above problem. A research and development project, supported partly by the Israeli Ministry of Energy and Infrastructure has been initiated, for assessing the technoeconomic feasibility of biogas technology in the Israeli Kibbutz. Several bench-scale and pilot scale plants were constructed by Haifa Technion Group, the KIA group of Tel-Hai Laboratory etc. in various typical Israeli Kibbutz. Two demonstration plants of 1000 l working volume are in operation successfully. The project is also experimenting with various uses of sludge like fish feed, livestock fodder, production of hard boards and particle boards, etc. The bench-scale experiments, pilot plants and semi-demonstration plants have established the potential of the technology in Israel. It is assumed that a high efficiency of 4 to 5 m^3 biogas per cubic meter digester per day can be reached at the demonstration and commercial levels.

Italy

Italy as a whole has 57 agricultural plants (39 pig farms, 8 dairy farms, 5 beef farms), 1 landfill and 10 industrial plants (1 sugar refinery and 9 distillery wastes). The total volume of Italian plants is over 45,000 m and 14 more plants are in plan or under construction. The largest installation is one in which the wastes from 24 neighbouring farms are collected into a primary digester of 7500 m^3 with a secondary digest of 2500 m^3. The biogas produced is used to generate electricity for irrigation. The industrial waste digesters treat the washings from the ion exchange resins of a very large sugar beet factory. The biogas produced is used in the factory where it makes up only 2-3% of the total consumption. However, the mass of experience being gained should prove very useful in the design of second generation digesters. An added impetus to the digester programme in Italy will be the introduction of a 50-60% grant for energy saving with the remainder being available on fairly easy loan terms.

Jamaica

Biogas Technology is comparatively new to Jamaica. A joint OLADE/Government of Jamaica Biogas Programme has been initiated in 1980-1981, under which 9 family size plants of the Chinese, Guatemalian and Mexican designs were installed in 1982. The programme further intends to establish more family size plants (to cater to the domestic energy requirements) and medium-sized plants in the country. Setting up a full-fledged biogas laboratory is also under-way. A few medium size biogas plants attached to institutions and cooperative farms, have been installed during 1982-83.

Japan

In Japan, anaerobic fermentation research and development was viewed more as an anti-pollution measure, rather than as an energy alternative. Since 1973, nation-wide efforts have been made to reduce pollution problems resulting from animal, human and industrial wastes. Several institutions like the National Institute of Animal Industry, Chiba, the Public Works Research Institutes, Fermentation Research Institute, Anage, Hitachi Plant Construction, the Ministry of Agriculture, and the Agency for Industrial Science and Technology have been working on anaerobic fermentaton of organic wastes.

Big plants to treat industrial wastes, particularly from alcohol distilleries have been set up. High temperature digestion in thermophilic range, especially for industrial wastes, is being adopted.

In 1974, the Sun Shine Project was initiated with the objective of developing new energy technology. Among other subjects the Project includes investigations into anaerobic digestion of animal, human and solid urban wastes.

Interest in small digesters has again been renewed. Small digesters, using a steel tank with an agitator and a water coil for heating the slurry, have been developed. The digester has a double wall for insulation against low temperatures.

Kenya

Since 1957, the Hutchinsson Tunnel Company has marketed biogas plants in Kenya. They are made of corrugated metal, built above ground and are available in different sizes for from 5-200 cows. However, they have proved economically successful only on farms with more than 20 cows.

Recently this German Technical Assistance Agency (GTZ) Special Energy Programme, under the auspices of the Ministry of Energy and Regional Development and Kenya Industrial Estates (KIE) has set up a special Energy Programme including Biogas. KIE's approach entails making an inventory of existing designs, modifying and producing prototypes of a range of products.

Under the Renewable Energy Programme initiated in 1982, KIE constructs family size biogas plants. The original models, built on site are made of stone walls lined with cement. A pilot project to test the viability of these models is underway at Kegio in Muranga, Khwisero in Kakamega, Limuru Boys' Centre and Kiriaini in Nyeri.

Initial monitoring of this design for about one year showed a high degree of acceptance of biogas technology. On a farm at Kegio, biogas has replaced all fuelwood requirements for lighting and cooking.

Because of various constraints such as organization of and high costs of labour, raw materials and transportation, a new prototype digestor was recently fabricated in a bid to mitigate these constraints. These pre-fabricated digestors, dubbed the "Gobar-Sasse" types are constructed out of ferro-cement, and installed with a back fire fuse to stop gas explosion. They cost about Kshs. 10,000-15,000 and are projected to have a ten year life-span.

The MORED/GTZ holds training courses for artisans in the construction of the Gobar-Sasse Model. A total to 58 artisains have so far been trained. Family size biogas plants have been shown to be viable in Kenya. On the community level, biogas plants are still fraught with technical and management problems, such as material procurement, water and tank management. Social organisation and land tenure pose additional problems.

The Ministry of Habitat is studying the feasibility of a community digester in a pilot project. The aim is to reach even the poor people with biogas, which is also the aim for some non-governmental organizations. For example, the National Christian Council of Kenya. The Catholic Secretariat, UNEP and UNICEF are trying to develop appropriate solutions to small farmers,

Malaysia

Biogas technology is new for Malaysia. Even though there are ample supplies of oil and natural gas, the Government has been giving attention to reducing dependence on conventional energy sources, especially on the part of small land-holders. One of the main hindrances to the propagation of biogas is the religious tradition which prohibits the handling of animal wastes, especially of swine. Many biogas plants have been installed for reasons of sanitation rather than energy production. Some oil palm plantations digest the waste materials as treatment before disposal. However, the gas produced, is not collected.

Research developments in biogas technology are co-ordinated by the National Institute of Scientific and Industrial Research.

Mexico

Approximately 85% of the energy consumption of Mexico is met by its oil reserves. About 80% of Mexico's territory is made up of arid and semi-arid lands. However, Mexico has got substantial livestock population with 31 m cattle heads, 7.32 m sheep, 6.3 m goats etc. and thus offers chances for biogas development.

Biogas Technology is in the process of development and widespread use in Mexico. The Ministry of Human Settlements is engaged in the construction, demonstration and popularisation of biogas plants in the rural areas. Besides the Ministry of Human Settlements, the Instituto de Investigaciones Metalurgicas of the University of the State of Michoacan, the Universidad Autonama Metropolitana-Ixtapalapa, Proyecto Xochicalli AC etc. are also engaged in research, design and development of Biogas Technology.

Innovations in plant models have resulted in the OLADE-Xochicalli-Mexico Model Biogas plant which is being tried out in several Latin American and Carribbean countries.

Nepal

The search for low cost alternative sources of energy is one of the main challenges of Nepal and biogas is playing an increasingly important role. The history of biogas in Nepal was started in 1952 by Father B.R. Saubolle even though serious attempts towards popularising the technology commenced only in the early 70s. Since then, many hundred plants have been built. At present, there are about 1200 biogas plants each with the capacity of producing 3 m^3 of gas/day which is sufficient to meet cooking and lighting needs of a family of six or seven.

1975-76 was an Agricultural year in Nepal, with special emphasis on biogas. During this year the research and development on biogas started. The "Energy and Development Research Group" was created at Tribhuvan University in 1975. His Majesty's Government of Nepal (HMG) provides interest-free loans through the Agricultural Development Bank (ADB) to those who wanted to build a 100 cu.ft. gobar gas plant of the KVIC steel drum design. The Development and Consulting Services of the United Missions to Nepal (DCS of UMN) were involved in this programme together with Butwal Technical Institute. These are some of the organizations involved in the biogas implementation programmes in Nepal.

The UMN have made efforts to reduce the cost of a biogas plant, using other materials than steel. Improvements in the conventional floating drum and fixed dome models are being made.

A special Nepali version of the Chinese model was developed, reducing material cost with 35% and total cost with 20%.

The Gobar Gas Development Committee, Department of Agriculture, HMG and SATA are publishing the Biogas Newsletter, which is an information journal establishing international contacts for people engaged in biogas use and research.

Netherlands

No state-coordinated plan for the development of methanogenesis is in operation in The Netherlands. However, work has been done for a number of years on new types of digesters for industrial biogas production.

The Department of Wastewater Treatment, at the Biotechnion, Faculty of Agricultural Sciences, in Wageningen, has developed the concept of upflow plug-flow tower digesters. The system is being assayed on the industrial scale in the C.S.M. (Central Suiker Maatschappij) near Breda in a tower digester of 1200 m^3 for the treatment of the waste waters from sugar beet conveyer belts and other waste waters of the refinery. The treatment of waste waters from the potato industry in Rixona Warfum, is also being assayed in five 40-m^3 upflow digesters.

At the University of Amsterdam, a joint venture between the Department of Microbiology and the Department of Chemical Technology is aiming at a better comprehension of the two-step anaerobic digestion process, and more particularly of the acidogenic step. At the Central Institute for Nutrition and Food Research of the T.N.O. (Toegepaste National Onderzoek) in Zeist, the possibility of producing biogas from fruit and vegetable wastes by anaerobic digestion is being studied.

Nigeria

Biogas Technology is in the initial stages of its adoption in Nigeria. A prefeasibility study to assess the availability of raw materials for biogas production was carried out by the Department of Microbiology, University of life, Nigeria. The study was as part of the Biogas Technology Development Plan for Nigeria. The study shows an estimated production of 0.46m^3/volatile solids of biogas per day per person from the urban waste alone. Other raw materials include agricultural residues, manures, Siam weed etc. In particular there is good prospects for an energetically and economically feasible poultry-dropping-based biogas industry in Nigeria, because most families rear chicken on a small scale and commercial poultry farms are also springing up daily. Family size plants can be maintained by adding variable amounts of kitchen wastes and night soil. In short, the study has established the economic potential and viability of biogas technology in Nigeria, especially in the rural areas.

Pakistan

At present there are over 2000 digesters installed in the country, but of these only about 600 are working satisfactorily. Almost all of them are of a Modified Indian (floating dome) design producing about 3 m^3 of gas/day from the dung of 3-5 cattle. This quantity of gas is sufficient for the cooking and lighting needs of one family of up to ten people. Such a unit costs about £175-200 half of which is taken up by the cost of the gas holder, but this may be provided free by one of the implementing organisations. The high cost of digesters is seen as one of the main constraints but the economics look attractive if the capital can be raised.

A family of ten might spend about £70 per year on wood or kerosene for cooking and lighting giving a payback period of 2-3 years without taking the fertiliser value into account. However, the main reasons for failure are poor management, lack of operator training, especially in the dilution of the cattle dung, and in after sales follow up. Of the technical problems, the most important seems to be the low gas yields during winter in unheated plants. An interest was expressed in large plants especially for use with the new "cow colonies" being set up outside major towns for several hundred cows each, and on intensive poultry units.

Papua New Guinea

Work on integrated biogas systems, which include necessary provisions for the utilization of effluent for growing algae and acquatic plants, pisciculture and fertilizer has been in progress since 1970. A bag-digester type of plant, much cheaper than the conventional design, is also being developed. The digester is made of 0.55 mm thick hypalon laminated with neoprene and reinforced with nylon sheet.

Peru

Interest in biogas technology is on the increase in Peru. A national biogas programme has been set up by about forty public and private institutions under the Instituto de Investigacion Technologica Industrial y Novmas Tecnicas (ININTEC). ITINTEC commenced its activities in biogas technology in 1976 and has so far installed 44 small scale biogas plants of the Chinese model run on vegetable and animal wastes. All except four of the installed plants are operating satisfactorily. The plants are made of local materials like bricks, stone, soil-cement and lime thereby reducing construction cost. The biogas produced is mainly used for domestic energy needs like cooking and lighting. Use of biogas in heating milk in rural cheese-making factories and running a four small power (5 hp) gasoline engines are also being tried out.

Philippines

There is no shortage of firewood. The interest in Biogas in the Philippines is based on pollution control and health aspects.

The research and development activities are carried out at the National Institute of Science and Technology (NIST), at the University of the Philippines at Los Banos and at Maya Farms.

There are more than 400 biogas units. About 100 units have been built under the control of NIST. They need manure from 5-10 pigs and provide a family of five with energy for cooking.

The University at Los Banos has developed an integrated biogas system. The slurry is used for the growth of Chlorella, fish and rice.

A piggery was established at the Maya Farms in 1972 and anaerobic digestion was investigated for treating the wastes. Now, there are 48 batch plants (2, 5 x 3 x 3 m) digesting the waste from 7,500 pigs. There are continuous digesters of the Indian and Taiwan designs. The daily gas production of the farm is 560 m. The gas is used for running engines, production of electricity cooking and water heating in the meat processing and canning plants, etc.

The Bureau of Animal Industry (BAI), in cooperation with the Energy Development Board, launched the Biogas ng Barangay Programme in 1980. This is a supervised credit scheme whereby farmers in rural areas, particularly livestock raisers, may borrow money from financial institutions to install biogas digesters. The BAI has also set up regional and provincial biogas demonstration projects. Biogas digesters have been installed in the breeding centres and stations of BAI in all twelve regions.

The responsibility for the extension work lays on the National Housing Authority (NHA), the Engineering Battalion of the Military, the Communitty Development Department and others, with NHA as a coordinator.

Poland

Some work was taken up in 1955, starting with investigations concerning the reduction of nutrient losses, especially nitrogen, in processing manures. A few pilot plants were set up in Skierniewicach around 1960 to investigate the kinetics of digestion at different temperatures and solid concentr-ations, along with manure quality.

Republic of Korea

With the objective of solving the rural energy problem, the Korean Government initiated a major biogas development progr-amme in 1969. Since then over 28,000 family size digesters have been installed through the efforts of the Office of Rural Development (ORD).

Research, development and dissemination are carried out by:Institute of Agricultural Engineering and Utilization (IAEU), the Rural Guidance Bureau (under ORD) and the College of Agriculture.

The IAEU experimenting with PVC and concrete fixed dome digesters. The College of Agriculture at Suwean is working on a two stage digester of reinforced plastic insulated with paddy husk.

The biogas plants in Korea are used in rural households. The size is 5,5 m^3 or 8 m^3. Most farmers do not operate their plants during winter, when the temperature is about - 20°C. Biogas saves about 200 hours of household work per family per year, when *it supplies 3-6% of home-heating and* 45% of the cooking needs.

Singapore

There is not much scope for small-scale biogas plants in Singapore. Biogas produced at the sewage treatment work is used for operation of dual-fuel engines to generate electricity.

Spain

Interest in anaerobic digestion developed much later than in other parts of Europe. The National Agricultural Research Institute, Madrid, has conducted biogas research. A few batch type digesters based on a French design were established. However, not much information is available on their performance.

Sri Lanka

Biogas technology is relatively less significant primarily because of the problem of availability of input materials especially animal dung. However, biogas research and development are being carried out by: the Government (Department of Agriculture), Industrial Development Board and the Asian Rural Energy Research Project Experiment Station etc. The Government plans to introduce subsidies to encourage the use of non-conventional fuels.

Switzerland

Switzerland is the country in Europe with the most farm scale digesters, and all built within the last three years. Before 1980, there were only twenty plants. 30 were constructed in 1980, and more than 60 during 1981. At the end of 1981 there were 102 working installations. It now has more than 150 plants working on farms.

Many of the digesters are small with about 70% of the plants lying in the range of 40-100 m treating the waste from 30-50 cows or 300-500 pigs. About 50% of the plants are made in concrete 30% in GFK and 20% in steel. These plants have been designed and constructed by about 20 companies of which three, LBA, W. Huber AG and Eigenbau have taken 70% of the market. Quite often the farmers have done much of the construction themselves although they usually call in professional advice for the design of the digester and supply of special materials etc.

The distribution of these plants is very localised and they are concentrated in the cantons of Vaux, Uri and Zurich. This has been caused by several factors of which the proximity to an installation which has been working satisfactorily for some time, and the presence of manufacturers who can offer an efficient follow up service are the major ones. The activities of 'Project Biogas', an association of farmers, manufacturers and researchers, has also been influential in spreading information about the process and in helping to get its acceptance by the farming community.

As a rule the plants are not very efficient producers of energy, but due to the strong influence of farmers in the design and development, they are simple and adapted to local conditions. The farmers have expressed their satisfaction with the process and this has been very influential in the spread of the technology to other farms.

The use of the gas has often been a problem, especially in summer when it is not needed for domestic heating. Each farm is different and different solutions have been found ranging from grain drying to the heating of hot water for cheese production. The production of electricity has not been easy and the sale of surplus gas is not encouraged by the resale price being only 50% of the buying price.

Taiwan

Biogas technology is in a fairly advanced stage of development in Taiwan. Input material used is pig manure. The Union Chemical Laboratories designed the Red Mud Plastic (RMP) biogas plant in 1967 and it has now become popular in Taiwan as well as other countries. There were over 7,500 family-size plants in Taiwan in 1975. The recent trend is to install large-scale plants for hog farms. During 1980-1983, the Union Chemical Laboratories alone have designed over 2,000 family-size plants (15-20 m^3) and 1,000 pilot scale (50-150m^3) RMP plants.

The Council for Agricultural Planning and Development has recently installed a large-size plant at a 20,000 head piggery. The sludge from the plant receives a secondary aerobic treatment with an aerator powered by a generator with biogas as the fuel.

Taiwan has also started R&D programmes for plant performance monitoring, better use of sludge for spirullina cultivation as well as demonstration and extension programmes for the rural farmers.

Tanzania

Tanzania is typical of an underdeveloped country with little indigenous industrial, technical, or educational infrastructure to build upon. Biogas has nevertheless received sufficient attention to give rise to two different models of digester. The SIDO (Small Industries Development Organisation) type is based on the Indian design and uses a single floating gas-holder made of mild steel. The AATP (Arusha Appropriate Technology Project) type is a derived design specifically intended to reduce the cost of the gas-holder.

SIDO has a Section specifically devoted to biogas training and extention. So far over 50 people have been trained in building, commissioning, and operating biogas plants. The Industrial Census shows that 95 digesters have been installed by SIDO in different parts of the country, about 60% of which are reported to be in working order.

Since their establishment in 1976, AATP have installed 104 digesters in Arusha and other Regions. AATP have also produced a simple illustrated instruction manual on the construction and operation of digesters.

The cost of building and maintaining plants has been rising rapidly and is a considerable deterent to the speed of their use. Operating problems have also been encountered. Reports have blamed lack of maintenance, difficulties in collecting cowdung, shortage of water, and lack of interest, for the failure of some installations.

Thailand

Biogas technology was introduced in Thailand in the 1960s by the Department of Health. The main objective was sanitation considerations.

The institutes involved in biogas development are: the Asian Institute of Technology, the Department of Animal Husbandry at Kasetsart University, the Department of Health and the Applied Scientific Research Corporation. Night soil biogas research is carried out at the sanitation center in Sara-Buri, near Bangkok, in collaboration with the Faculty of Public Health. From the Health Department sanitation officers travel to the villages to inform about biogas and to arrange the delivering of biogas plants.

There are some 4,500 biogas plants in operation in Thailand. They are mostly small-scale plants used for domestic purposes. Several problems have been encountered with respect to their cost and efficient operation. One challenge in the development of biogas technology is to convince the farmer of the practical usefulness of anaerobic fermentation to obtain fuel from his refuse material while still maintaining its fertilizer content. If biogas technology is to expand rapidly in Thailand, it is important to develop simple low-cost equipment that can be installed by the villager himself, run economically and at the same time produce sufficient gas to meet his fuel requirements.

Union of Soviet Socialist Republics

The first digester seems to have been set up in Georgia in 1948. During the 1950s, biogas research work was taken up at institutions like the All-Union Research Institute of Fertilisers, Agronomy and Soil Science, Moscow. A large-size experimental plant has been in operation in Tulskoi since 1957. The digester design is similar to the "Allerhop" or "Dresden" designs. Between 30 and 60 per cent of the gas produced is used for heating the digester. Five large-scale biogas digesters are known to have been in operation in 1958. However, these installations were found uneconomic later.

United Kingdom

No state-coordinated plan for the development of anaerobic digestion is presently being used in the u.k., although the Energy Technology Support Unit of the Department of Energy has carried out a number of resource assessments. A number of public and private projects are, in progress.

The Rowett Institute, Aberdeen, is engaged in the study of the fundamental microbiology of the methane fermentation process. With the help of P. Mills of the North of Scotland College of Agriculture, in Bucksburn, Aberdeen, Scotland, applied research has been conducted since 1968 on the conversion of animal wastes to methane both as obtained and in mixture with other agricultural wastes. Two pilot-scale plants of 13 m^3 each have been used. A full-size digester is planned to be located on a large pig farm.

A joint team from the Polytechnic of Wales, and the University College, Cardiff, is engaged in studying biogas production, mainly from sewage sludge, and eventually from animal wastes. Mixing by gas recirculation has been studied, leading to the design of an appropriate flat-shaped digester. Hydraulic retention times are made shorter than solids retention times by using a settling device built within the digester from which only the supernatent effluent is removed. The design has proven successful in a 1 m^3 digester, constructed by Hamworthy Engineering Ltd., in Poole, Dorset. Solids retention time in this digester could be reduced to 3 days. A similarly designed 30 m^3 steel prototype plant will be constructed in Dorset, and there are plans for a full-scale digester of 250 m^3 for a pig farm in Suffolk.

Biomechanics Ltd., at Smarden, Ashford (Kent), has developed a process for biogas production from trade waste waters with concentrations of around 2% dry matter.

Farm Gas Ltd., in Bishop's Castle, Salop, is marketing classical, completely-mixed plants from 1.5 to 400 m^3, intended for a wide variety of wastes, but mainly for large pig-fattening farms.

Some publicly supported projects of R&D in biogas production include the following: Anderson and Donnelly at the University of Newcastle-upon-Tyne,the Intermediate Technology Development Group at Imperial College, London, the Wolson Foundation at the Biotechnology Unit of the University of Strathclyde in Glasgow, Natural Energy Systems in Edinburgh at the Leicester Poly - technic, Leicester, the Microbiology Department, Queen Elizabeth College in London, etc.

U.S.A.

Dairy farmers in the U.S.A. are investing in biogas plants as an additional farm profit centre. The three key factors responsible for this development are : (i) relatively low cost below ground, plug flow system (Cornell design), (ii) high gas yields (1.5:2.0 units gas produced/unit of digester volume per day, (iii) the successful implementation of a Federal law, which requires electricity supply companies to accept electricity generated from a renewable source of energy as a priority on their Grid and, moreover, to pay a realistic price for it. The ability to be able to supply a constant electrical demand at a realistic price, itself, makes the difference between profit and loss on the investment. In addition, because the engine runs constantly, and therefore remains at its working temperature, the condensation of noxious sulphureous compounds is minimised, prolonging engine and exhaust heat exchanger life.

Viet Nam

Tuliem Agricultural Sation and the Institute for Electricals and New Energies, Hanoi, are involved in biogas research. Aspects like use of local construction materials, design of clay burners, and the use of different feedstocks and their mixtures are being investigated. A few demonstration units in different regions have been established Two technicians have been trained in India under the FAO/UNDP programme. A national biogas development programme is being considered by the Government.

CHAPTER - 16

GUIDE TO DOCUMENTARY SOURCES OF INFORMATION

16.1 Introduction :

In keeping with the development of biogas technology there has been an increase in the literature output on the subject. over 1500 articles and information materials on the development, application and promotion of the technology have been generated in English language alone.

Literature on biogas started appearing in journals as early as 1920s. In fact, about 6% of the 1500 articles analysed seem to have been generated during the period 1920-1950. Since then there appears to have been a lean period in biogas-related activities because only 23% of the literature output has been reported during the period 1950 to 1975. However, the decade 1975-85 witnessed a spurt in biogas literature output presumably as a result of the renewed interest in biogas and its uses. Nearly 71% of the total literature output has been during the last ten years.

As regards the different types of information sources, conference papers and journal articles form the two principal sources. Papers presented in conferences/symposia/seminars etc are seen to constitute over 46% of the total literature. Besides such papers, this category also includes chapters/parts of a composite book dealing with a larger or related aspect and in which biogas technology also has been covered.

Apart from conference papers, journal articles form the other major source of biogas information. Approximately 44% of the biogas information appears in the form of articles in journals. In addition, a few reports, progress papers, feasibility studies, evaluation papers, development plans etc. have also been generated from institutions and agencies involved in biogas related activities.

Quite significantly, some similarity can be noticed in the nature of the two major sources of biogas information. Both journal articles and conference papers are found to be highly scattered especially so in the early stages of biogas development. The conference papers have been presented in over 100 seminars/symposia/ meetings in a wide range of topics like bioenergy, agriculture, engineering etc. Similarly, journal articles seem to have appeared in about 220 different journal titles primarily devoted to varied subjects.

Of late, a few conferences/symposia specifically on biogas technology or bioenergy in general are being held periodically. Similarly few journals on bioenergy and biogas technology have also started publication. These developments are hoped to reduce the degree of scatter of biogas information.

In the present chapter, a brief description of some of the important sources of biogas information such as conferences, journals, reports, etc. has been give.

16.2 Conferences/Symposia.

International Symposium on Anaerobic Digestion.

This is perhaps the only regular symposium specifically on anaerobic fermentation. The First International Symposium was held in 1979 in the University College of Cardiff, U.K. The second, held in 1981 in Travemunde of West Germany had participation from about 35 countries. The third one was held at Boston in 1983. The sessions are devoted to microbiological and biochemical aspects of anaerobic digestion, engineering and design characteristics of biogas plants as also some case studies on biogas systems in operation.

E.C. Energy from Biogas Conference.

Organised by the Commission of Europen Communities, DGXII, rue de la Loi, 2000, B-1049, Brussels, Belgium, the Conference is intended to provide a permanent platform for the exchange of new ideas and developments on the technical and socio-economic aspects of biomass energy. The Conference generally has sessions devoted to the production and use of biogas.

Invited lectures, oral presentations of submitted papers and poster papers are edited and brought out under the title Energy from Biomass by Applied Science Pub., Ripple Road, Barking, Essex, England.

Energy from Biomass I, Proceedings of the 1st EC Conference, Brighton, 4-7 Nov. 1980; ed by W. Palz and others. 1981.

Energy from Biomass II, Proceedings of the 2nd EC Conference, Berlin, Federal Republic of Germany, 20-23 Sept. 1982 ed. by A. Strab and others. 1983.

Energy from Biomass III. Proceedings of the 3rd EC Conference, Venice. 25-29 March 1985. (to be brought out)

Miami International Conference on Alternative Energy Sources, Miami Beach, Florida.

The Miami Conference is a periodical Conference, offering a forum for the leading energy scientists, economists and planners from over 40 countries to meet and present latest advances on aspects of Alternative Energy Sources. The first Miami International Conference was held in 1977. The latest and 7th of the series is scheduled to be held at Miami Beach from December 9-11, 1985.

The first three Conferences had dealt with the process of anaerobic fermentation for biogas production in a very general manner. However, with the increasing relevance of biogas technology for fuel and fertiliser production, the subsequent Conferences had technical sessions devoted to Bioconversion with special reference to Biogas Production.
The proceedings of each Conference are generally brought out in the form of a multivolumed set entitled Alternative Energy Sources. The proceedings, edited by Nejat Veziroglu of Clean Energy Research Institute, has been presented by the Clean Energy Research Institute, University of Miami, Coral Gables, Florida, in cooperation with International Association for Hydrogen Energy, International Atomic Energy Agency, International Solar Energy Society, Florida, the Florida Solar Energy Centre, and the Mechanical Engineering Department, University of Miami. The set is published and printed by Elsevier Science Publishers, 52, Vanderbilt Avenue, New York, NY 10017.

Symposium on Energy from Biomass and Wastes.

The symposium held periodically since 1976, is sponsored by Institute of Gas Technology, IIT Center, 3424 South State Street, Chicago, Illinois 60616. So far eight such symposia have been held. The papers of all symposia are generally published under the title Energy From Biomass and Wastes".

The papers on biogas production are generally those with special reference to developed countries.

Biogas Technology : Proceedings of the National Seminar on Biogas Technology. 9-11 July, 1981, **Ludhiana,** USG Pub 1983. 165 p.

The seminar was organised with a view to reviewing the present status of the technology as well as to affording an opportunity to the researchers, extension workers, public and private agencies engaged in biogas-related activities for information exchange. The seminar was organized with the support of ICAR/UNESCO Centre of Advanced Studies in the College of Agricultural Engineering and the Dept. of Science & Technology, Govt. of India. The papers presented deal with various aspects of biogas technology like contemporary development of biogas technology in India and China and their present status chemistry and microbiology of anaerobic processes, economic aspects of biogas technology, integrated energy, from renewable sources, biogas plant operation, mathematical modelling of biogas designs, etc. A special invitee Dr. E.L. Halwagi of National Research Centre, Cairo, Egypt, presented an excellent account of status of biogas technology in Egypt.

Vyas, S.K. and Grewal, N.S. ed.

Biogas Workshop, Bombay, 8-1- September 1980.

The workshop was organised by the Commonwealth Science Council and the Khadi and Village Industries Commission, India. Technical sessions were devoted to themes like biogas technology for rural areas, country studies, CSC alternate energy programmes, Regional Project Proposal and identification of elements for inter-regional cooperation, etc.

Construction Manual on Janata Bio-Gas Plant. FAO/UNDP Practical Training Course on Low Cost Biogas Technology, Varanasi, Dec. 28, 1981 to Jan. 14, 1982. 49p. Diagrams.

Construction Manual on Janata Bio-Gas Plant. FAO/UNDP Practical Training Course on Low Cost Biogas Technology, Varanasi, Dec. 28, 1981 to Jan. 14, 1982. 49p. Diagrams.

The objective of the training course was to expose the participants to the constructional aspects of three different designs of biogas plants namely the flexible drum type KVIC model, the Janata Model and the Shanghai model. The present manual, as the name goes, gives a detailed description of the construction techniques, start up and operational procedures of Janata Model Plants. The text is supplemented with a number of plans and sectional elevations of the plant.

Myles, Raymond M. and Dhussa, Anil K.

DST-MACS Training Course on Microbiological Aspects of Biogas Production.

The course was organised by the Dept. of Microbiology, Maharashtra Association for Cultivation of Sciences, Law College Road, Pune 410 004, India, with the help of financial assistance from the Dept. of Science and Technology, Govt. of India. The training was conducted with a view to facilitate institutions taking up studies on microbiological aspects of biogas production. The course included practical laboratory tests on aspects like preparation of nutrient media for anaerobic bacteria. violation and identification of methanogenic, cellulolytic and dissimilatory sulphate reducing bacteria, chemical and gas chromatographic analysis etc. The organisers of the course have brought out a laboratory manual also for the purpose of wider distribution.

Internationl Biogas Workshop. Bremen, May 16-20, 1979 organised by German Agency for Technical Cooperation and Bremen Senate for Economic Affairs and Foreign Trade. Report. Bremen, Bremen Overseas Research and Development Association. 1979. 311p.

The workshop was concerned with strategies for the introduction and implementation of biogas. The specific aim was to organise an international exchange of experiences and also to discuss some draft material for the intended edition of a Biogas Manual which had been presented by BORDA.

Report contains four main elements: participants' reports on biogas in their countries, draft papers, a summary of the workshop discussion and some hints concerning materials, media etc. which the participants presented at the workshop.

Biogas activities of over 15 countries were reported during the sessions. This included countries like Belgium, Cameroon, China, Columbia, Ethiopia, Germany, Ghana, India, Korea, Philippines, Rwanda, Switzerland, Tanzania, Thailand, Upper Volta, etc. The performance of the technology in several countries as reported in the above papers was indicative of the need for some tools/ techniques for its popularisation. Discussions were hence concentrated on further disseminating evaluation of the technology in developing countries in the form of a document. The results of the evaluation and the conclusions derived are given in the form of about 156 thesis/units for publication as a Handbook. The draft of a Biogas Field Manual was also discussed.

International Biogas Workshop on Community Plants, Bremen, Federal Republic of Germany, May 1984.

The workshop was organised by Bremen Overseas Research and Development Association (BORDA) in cooperation with the German Agency for Technical Cooperation (GTZ) and the State Office for Development Cooperation of the Free Hanseatic City of Bremen. The workshop specialised in Community Biogas Systems including Cooperative Plants, Public Plants and Commercial Plants with digester volumes from 20 to 200 m capacity. Papers presented dealt with the various aspects of community plants in countries like Botswana, Ethiopia, Guatemala, India, Nepal, Thailand, Vietnam, etc. For the benefit of those who did not participate in the conference, BORDA has brought out a volume which contains all the documents presented.

Orientation Course on Biogas Development. India, Ministry of Agriculture. 1982.

The orientation course was organised under the National Project for Biogas Development of the Ministry of Agriculture. The first of the series was the Programme for Inaugural Session, held at SPBT College from 5-6 March 1982. The course was organised by Agricultural Finance Corporation Ltd., Bombay 400 039, in collaboration with the Commission (Fertiliser Promotion), Ministry of Agriculture, Govt. of India. Sesseions were devoted to the national programme, role of state governments, training and extension community plants, financing biogas plants, etc.

As part of the programme, another orientation course was held at the Dept. of Farm Machinery, College of Agricultural Engineering, Tamil Nadu Agricultural University, from 11 to 12 March 1982. The course was again sponsored by the Ministry of Agriculture and discussed various aspects of implementing biogas developed programmes at the state level.

Trainers Training for Biogas Development, 5-25 March 1982, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore 641 003.

Trainers Training for Biogas Developed, 5-25 March 1982, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore 641 003.

The training programme was organised by the Dept. of Farm Machinery, College of Agricultural Engineering, Tamil Nadu Agricultural University, as part of the National Project on Biogas Development. The training course sponsored by the Ministry of Agriculture, Govt. of India was divided into major divisions. While the forenoons sessions were devoted to lectures on various aspects of biogas technology, the afternoons were meant for practical classes on the construction of the Janata Model biogas plant, operation and start up of the plant as well as cooking experiment, plant leak testing etc.

16.3 Journals

Abstracts of selected Solar Energy Technology (ASSET)

The publication and distribution of ASSET is an activity of the Energy Systems and Policy Sub-programme of the United Nations University. The purpose of **ASSET** is to provide scientists and engineers working in developing countries with abstracts of recent books, articles, reports and conference papers concerning solar, bioconversion and wind energy technologies and the socio-economic impacts of their introduction.

Each issue contains abstracts of recent books, articles, reports and conference papers concerning solar, bioconversion and wind energy technologies and the socio-economic aspects of their utilization. Issues contain abstracts of recent publications balanced with those from the extensive older literature. Care is taken to include all available information applicable to rural communities in developing countries. Each issue also includes at least one complete reprinted paper. The abstracts are classified into the following categories:

A. General

B. Solar Energy

B1. Radiation Measurement

B2. Photovoltaic Conversion

B3. Active Thermal Systems

B4. Passive Thermal Systems

C. Bioconversion Energy

C1. Biomass Production and Conversion

C2. Biogas Production and Utilization

C3. Alcohol Production and Conversion

D. Wind Energy

E. Energy Storage

F. Socio-Economic and Environmental Aspects

Periodicity

Monthly; 12 issues per volume

Price

$25/- by Sea Mail, $40/- by Air

Editor

Walter Shearer

Publisher

ASSET, The United University, Toho Seimei Building, 15-1 Shibuya 2-chome, Shibuya-ku, Tokyo 150, Japan.

Agricultural Wastes

Agricultural Wastes is an International Journal providing a forum for original papers concerned with all aspects of the management or treatment of agricultural wastes. The term 'agricultural wastes' covers not only the excreta from animals and birds, but also crop and forest residues, agricultural chemical residues, wastes from processing of animal and vegetable matter on farm or in factory, and wastewaters from food processing plants. The term 'pollution' includes health hazards to man and/or animals. The journal therefore contains papers describing methods of handling of animals or excreta, or physical, biological and chemical treatments of excreta so as to reduce pollution in the farm or wider environment. Since such treatments may produce energy or other useful by-products, papers describing processes whose primary aim is production of, for instance, animal feedstuffs, microbial or other proteins, gas and oil, from animal excreta are also published. Similarly, there are papers covering both aspects of treatment of wastes from meat, fruit and vegetable processing.

Papers describing laboratory, pilot-plant or full-scale experiments, which may be generally applicable or may apply only to certain types of farm or climatic conditions, and long-term experience with full-size plants or management systems are also included, as also are papers dealing with model systems and the theoretical aspects of agricultural waste management.

Types of contributions include Original papers; Review articles; Case studies; Short communications; Reports of conferences and meetings; Book review; Letters to the Editor.

Periodicity

Four issues per volume-three volumes per year. The £ sterling price is definitive, US$ prices are subject to exchange rate fluctuation. All prices include postage and packing. subscriptions for delivery to USA, Canada, Japan, China and Australia are air-speeded at no extra charge. Subscription orders to: Elsevier Applied Seience Publishers Ltd., Crown House, Linton Road, Barking, ESSEX /G118JU England.

Price

Subscription price for 1985 (Volumes 12, 13, 14); UK delivery, £186.00; Overseas delivery, £228.00/$308.00

Publisher

Elsevier Applied Service Pub. Ltd.
Crown House, Linton Road,
Barking.
Essex IG11 8JU, England

Anaerobic Digestion Mircen

Is a series of teleconferences using the

Computer Conferencing System (COM) at the Computing Center (QZ) at Stockholm University. These teleconferences are open to anyone with a COM account. AD-M is organised by the UNEP/UNESCO/ICRO Microbiological Resources Center at Karolinska Institute, Stockholm. It aims (i) to link individuals and organizations that the interested in methanogenic anaerobic digestion, either directly via COM or through the printed version of the teleconference series; (ii) to facilitate the exchange of information, (ii) encourage discussions and to help one another in their technical questions and problems.

AD-M currently has 4 teleconferences in the series, they are:

Anaerobic Digestion (MIRCEN) Technical
Anaerobic digestion (MIRCEN) Cocktail
Anaerobic digestion (MIRCEN) (at BIOENERGY 84 (Gothenburg)
Anaerobic digestion (MIRCEN) Evaluation (of) Biogas COMCON

Periodicity

2 issues per volume; 1 volume per year

Organizer : Mr. Eng-Leong Foo

Editors : Mrs. Frances van Sant
Mrs. Agnes S. Foo

Address : UNEP/UNESCO/ICRO
Microbiological
Resources Center
Karolinska Institute
S 104 01 Stockholm

BABA Digest

This is the Newsletter of the British Anaerobic and Biomass Association (BABA) Ltd. The Journal welcomes articles, letters or general comment related to the commercial production and use of biomass and organic wastes.

Periodicity

Semi Annual

Price

£ 10/- (UK) £ 20/- (Overseas)

Membership of BABA Ltd is restricted to British registered companies and institutions or British nationals. There is no restriction for subscribers.

Publisher

The Secretary, BABA, Limited,
The White House,
Little Bedwyn, Marlborough,
Wiltshire SN8 3JP, U.K.

Bio-Energy Renews

This is a journal of Energy from Biomass and Waste Recycling.

Periodicity

Bimonthly : 6 issues per volume.

Price

Rs. 125/- (India) $ 50/- (Overseas)

Editor

Dr. S. Paul

Publisher

India House Developments,
134 G, Palam Colony
New Delhi - 110 045.

Biomass

The journal covers all aspects of the production, processing and use of plants, microorganisms or enzymes for energy, fuel or chemical production. This includes basic microbiological and enzymatic studies in which anaerobic digestion and fermentation play a role in energy production.

The journal is essentially concerned with the use of biomass as an alternative energy source. Topics include the role of biomass and the energy situation; the resource base and possible significance in developed and developing countries; global recycling and environmental factors; photosynthesis and its efficiency as related to plant (biomass) productivity; sources (forestry, agriculture, horticulture, mariculture, aquatic systems, energy farms, etc.), composition and products of biomass; processes for the conversion of biomass to heat, fuels or chemicals, e.g. fermentation, anaerobic digestion, combustion, pyrolysis, gasification, hydrogenation, hydrolysis, etc.; production of electricity; use of biofuels (ethanol, methanol, hydrogen) in engines, wood-fired steam engines, straw burners, etc.; production of new chemicals or chemical feedstock from plants, new processes for producing chemicals from plants; energy balances and studies of economics; case studies at village and/or national level; future prospects of improving artificial photosynthesis.

Types of contribution

Original papers; review articles; case studies; short communications; reports of conferences and meetings; book reviews; letters to the Editors: forthcoming meetings.

Periodicity

Four issues per volume-three volumes per year.

Price

Subscription price for 1985 (Volumes 6,7 and 8): UK delivery, £ 160.00; Overseas delivery, £196.00/$265.00

Publisher

Elsevier Applied Science Publishers Ltd., Crown House, Linton Road, Barking, Essex IG11 8JU, England.

Biomass abstracts

This is published by the Biomass Information Service of IEA and CEC. The International Energy Agency (IEA), founded in 1974 by member countries of the Organisation for Economic Cooperation and Development (OECD), was set up to examine ways in which member countries could co-operate to reduce their dependence on imported oil, Twenty of the twenty-four member countries of the OECD participate in the IEA and the Commission of the European Communities takes part by special arrangement. Member countries were asked to take the initiative in establishing collaboration in relevant fields of Research and Development.

Ireland was invited to take the lead in establishing a Biomass Information Service and in May 1978 the Implementing Agreement establishing the Biomass Conversion Technical Information Service was signed. The function of the Service is to provide participating countries with a regular source of information on scientific and technical data in all areas of energy from biomass, including production, harvesting, collection, processing, transportation and conversion techniques:

Periodicity

Bi-Monthly

Price

United Kingdom, United States and the Commission of the European Communities. IR £ 54/-

All other countries :-

Nonprofit making organisations-IR£80
Profit making organisations-IR£160.

Publisher

Biomass Conversion Technical Information Service, Institute for Industrial Research and Standards, Ballymun Road, Dublin 9, Ireland.

Changing Villages

The journal is published by CONSORTIUM which is a National Association of non-governmental, non-profit organisation established to promote the development, growth and Improvement of technologies, helpful for the development of rural areas.

The journal on rural technologies is intended to serve as a forum to technologists to publish their studies and articles on the innovations and developments, they are working on; accounts of programmes of its members, as well as other non-governmental and governmental programmes on the subject.

The July-August issue of Changing Villages was published as a special issue as Biogas.

Periodicity

Bi-Monthly

Price

Rs.45/- (India) $20/- (Overseas)

Publisher

Consortium on Rural Technology A-89, Madhuvan, Delhi-110092 & printed by him at Shanti Printers, H-57, Lakshmi Nagar, Delhi-110092.

Reports

Biogas in Asia: Inventory Field Study on the State of Development of Biogas Digesters for Household Use in Tropical Rural Communities.

Biogas in Asia: Inventory Field Study on the State of Development of Biogas Digesters for Household Use in Tropical Rural Communities. Ultrecht, Consultants for Management
The study conducted by the Consultants for Management of Development Programmes bv. Achter Clarenburg 25, 3511 JH Ultrecht, Holland, was conducted with the help of financial support from the Netherlands Ministry of Development Cooperation.
It offers an analysis of "the state of the art" of biogas technology based on discussions with and observations by different level functionaries and persons involved in the "biogas movement" in Asia. Areas covered included countries like India, Thailand, Indonesia, Singapore, Hong Kong and Taiwan. Through analysis of aspects like the plant models developed and in use in the country in question, organisational set-up made available to beneficiaries, financial support extended, arrangements for training and extension, etc. have been reported. More significantly a discussion on the ultimate impact of digesters on the socio-economic status of the different target groups and the reasons for the differences in technology acceptance.

KIJNE, Erik, Ultrecht, Consultants for Management of Development Programmes by 1984. xiii. 121 p. Tables, Plates.

Bio-Gas Plants : A Challenge to Rural Entrepreneurs.

Bio-Gas Plants: A Challenge to Rural Entrepreneurs. Ahmedabad. IIM, 1982. 35p. Tables.

A report of the Indian Institute of Management, Ahmedabad, this study examines the strategy adopted by the Govt. of India to encourage salting up of small-scale individual farm-based plants on large-sized community plants through subsidy. The social-cost benefit analysis of individual as well as community plants has been worked out and many a technical, operational and management difficulties are pointed out. This is with a view to studying the strategy of setting up of bio-gas plants on a commercial basis by rural entrepreneurs.

DESAI, D.K. Ahmedabad. IIM, 1982. 35p. Tables.

Biogas Systems in India. Virginia, VITA/ COSTED.

This study is a timely one in that it appeared when India was initiating biogas popularisation in a big way. Addressed to the rural utilisation of biogas systems, the study is an assessment of the "appropriateness" of biogas technology in meeting some of the needs of India's rural population. After assessing the rural energy consumption and biogas potential for rural India, the author provides a brief overview of biogas systems. This is followed by a review of the various plant models in operation in India as well as a description of the present practises of gas distribution and use. Equally significant are the chapters giving an overview and economic analysis of community biogas systems.

LICHTMAN, ROBERT JON 1983. vi, 130p. Diagrams, Tables, Charts.

Biogas Technology and Utilisation : A Status Report.

The Department of Science and Technology, has sponsored R&D programmes for the development of biogas technology. Under the first phase of the coordinated multi-institutional project of the Department of Science and Technology, investigations on cost reduction, design of plant, various types of feed materials, operational parameters, microbiology, fermentation kinetics, designs of various types of gas appliances, socioeconomic studies etc. were undertaken. Several notable results have been obtained. Under the second phase of the project, work on community-type biogas plants has been initiated, and the improvements resulting from R&D programmes are being field-tested. The present Status Report is intended to help to inform scientists, technologists, planners and administrators, as well as the public, on the present state of biogas development, as also the potential and problems, if any, of biogas contributing significantly to the national energy scene.

INDIA, Dept. of Science and Technology New Delhi, 1981. ii, 94p. Tables, Diagrams.

Biogas Technology in Developing Countries: An Overview of Perspectives.

In view of the over optimism and over-pessimism generally shown towards biogas technology this document is intended to set the topic in a realistic perspective. Hence, this report gives a critical review of the development and performance of the technology in certain developing countries. The coverage of this review has been deliberately narrowed down to family size system in developing countries. Results obtained in various developing countries in trying to implement biogas schemes vary considerably and judiciously present the various controversial opinions.

TAM, D.M. and THANH, N.C. Bangkok, ENSIC, 1982. 67p.

Community Biogas Plants : An Evaluation.

The report has been prepared for the Energy Panel of State Committee on Science and Technology, Govt. of Andhra Pradesh as part of generating detailed studies on the use of renewable sources of energy. The project was carried out with a view to examining the problems and prospects of community size biogas plants in India. Four community plants representing four different management systems/characteristics have been studied in detail for the purpose.

The report shows that community biogas plants are financially viable proposals for India. However, for their successful functioning and sustained use, the study suggests certain methods like introduction of programme monitoring for collection of field data, ensuring proper interaction with users, bringing about standardisation of design for community plants, arranging for proper organisational support for plant management etc.

BOWONDER, B. and others Administrative Staff College of India and Institute of Public Enterprises. 1984. 48p. Tables.

Dry Fermentation of Agricultural Residues: Annual Sub-contract Report 1 January 1980 to 31 December 1980.

The report was prepared as an account of the work sponsored by the Department of Energy, Government of United States. It covers the first-year results of a planned three-year program to develop a dry fermentation system to convert agricultural residues to methane. The dry fermentation system is expected to be particularly applicable to conversion of commonly available crop residues such as wheat straw corn stover.

The present report lays emphasis on defining the process of dry fermentation. Majority of the present effort was towards determining the kinetics of dry fermentation at bench scale and pilot scale with two crop residues and dairy cow manure mixtures. Major variables investigated during the period under study include temperature, inoculum (amount and kind) and buffer requirements. Preliminary studies in these aspects have shown very positive indication of the potential of dry fermentation systems for treating agricultural residues.

JEWELL, W.J. Golden, SERI, 1981. xxix, 484 p. Graphs, Tables.

The Feasibility of Biogas Productions on Farms.

This study was prepared for the U.S. Dept. of Energy under a contract to the Biomass Program Office of the Solar Energy Research Institute. The general objective of the project was to conduct a feasibility study of the role of anaerobic digestion on U.S. farms. The present report provides an overview of the anaerobic fermentation of farm wastes. After a brief survey of the potentials and limitations of anaerobic digestion, the report presents an analysis of the potential gas yield and farm energy generation relationship. The third chapter deals with the economic analysis of farm-scale biogas production. The various design considerations of the farm-scale biogas system are reviewed in the subsequent chapters. Methods for coordinating the farm energy supply (from biogas) with its energy demands and the different areas of biogas use are given in Chapter V. Other aspects covered include safety-guidelines and regulations, operation, maintenance and diagnostics of small biogas plants etc.

JEWELL, W.J. and others New York, State College of Agriculture and Life Sciences. Jan. 1982. xvi 163 p. Tables, Charts, Graphs.

Gobar Gas Plants in Punjab : An Evaluation.

This report is the result of an Evaluation Survey on Gobar Gas Plants in Punjab, undertaken on the recommendation of the State Evaluation Committee, Punjab, and is prepared by the Economic and Statistical Organisation of the State. The purpose of the survey was to assess the loaning pattern for plant installation, their working, attitudes of beneficiaries towards the scheme, promotion constraints, etc. The survey was conducted in about 30 villages in Punjab. Biogas situation in Punjab has been studied after conducting a detailed analysis of parameters like socio-economic characteristics of plant owners, types of plants and stoves in use, location of gas plants, rate of use of cowdung for biogas production, types of uses of biogas sludge, motivating factors of the beneficiaries, views regarding the capacity and use of plants, effect of financial incentives on adoption etc. etc. A set of recommendations for efficient popularisation of plants is also given.

PUNJAB, Economic Adviser, Chandigarh, Govt. of Punjab. 1983. vi, 69p. Diagrams, Tables.

Socio-Economic and Feasibility Report of the Community Biogas Plants Systems of Village Dadu, Dist. Gurgaon, Haryana.

This report has been prepared by AFPRO at the request of the Indian farmers and Fertilisers Cooperative Ltd. (IFFCO), New Delhi. The objective of the study was to propose and design a community biogas plant system for IFFCO, as well as to ascertain how the system can be integrated with socio-economic life of the villagers.

MYLES, RAYMOND. Delhi, AFPRO. 1982 69p. Tables, Drawings.

Books

Bio-Gas: Achievements and Challenges.

This is perhaps the first ever document where a comprehensive coverage of the topic biogas technology is given. Several of the chapters need to be updated, because the scientific developments in biogas production have been taking plan at a rapid rate and the technology is becoming popular in several countries of the Southern Hemisphere. However, this document still can serve as the start-off point for the study of biogas technology.

Virtually all aspects of biogas production has been discussed as can be seen from the chapter headings. Chapters deal with the need for biogas plants, a short description of the historical development, the basic principles and parameters for biogas production rate and quality, various uses of biogas and the sludge and how to plan and choose a biogas plant. Detailed descriptions of the various plant models all over the world supported by diagrams and illustrations is another significant feature. The economic aspects of biogas plants have also been considered in brief. At the end, planning and policy making implications for India, e.g. tasks for future research, parameters for building the infrastructural facilities are also given.

SATHIANATHAN, M.A. New Delhi, AVARD. 1975. xxvi, 192p. Diagrams, Tables.

Biogas: Manual for the Realisation of Biogas Programmes.

The manual, intended to serve practical application, deals with the implementation of biogas programmes in developing countries. It presents a political argumentation concerning biogas technology to consider its relevance, as well as problems on promotion in Chapter I. Then it goes on to discuss the planning of biogas plants, i.e. the characteristics of the region/area, favouring factors as well as possible changes, questions like community plants or family size plants etc. The 3rd chapter deals with the implementation programmes to be formulated. The last two chapters give some basic information regarding the technolgy and the benefits of the products of fermentation.

Eggeling, G. and others. Bremen, BORDA, 116p. Diagram, Tables.

Biogas: Production & Utilization.

Biogas: Production & Utilization. Ann Arbor Ann Arbor Sc. 1981. vi, 146p. Tables, Graphs

One of the few technical documents in which the process of biogas production has been reviewed from a microbiological and biochemical viewpoint. The book thus considers the biological conversion processes, especially anaerobic digestion, in the context of the growing costs of energy sources well as the increasing problem associated with waste disposal. The book can be considered in two main parts: the first part where the chapter is devoted to specific microbiological and biochemical processes like the different stages of anaerobic fermentation, factors affecting the anaerobic process, denitrification processes and systems, process kinetics, etc. The second part is chiefly oriented to conditions in the United States. Chapters deal with the application of the anaerobic process for treatment of materials like animal waste, municipal solid wastes, food processing wastes etc. for the purpose of energy recovery. The basic principles of biogas plant designs, instrumentation for gas measurements, methods of sludge treatment etc. are also given.

PRICE, Elizabeth C. and CHEREMISINOFF, Paul N. Ann Arbor, Ann Arbor Sc. 1981. vi, 146 p. Tables, Graphs.

Biogas and Waste Recycling: The Philippine Experience, Manila, Maya Farms Div. 1978. xx, 230p. Tables, Photographs.

This book is a summary of the experience of Liberty Flour Mills, Inc., Maya Farms, in their attempts to solve the pollution problems of their integrated livestock farm, meat processing and canning operations. After several alternatives were tried out, for waste disposal, anaerobic fermentation was chosen and adopted and the book gives a thorough discussion of the biogas system at the Liberty Flour Mills, Inc.

The book is essentially divided into 4 parts. While Part I gives scientific information on the nature and history, biochemical microbiological reactions, laboratory and pilot plant experiments, etc., Part II is devoted to information on suitable plant models for different condition. Several of the common designs have been presented together with a detailed discussion on the biogas wastes developed by Maya Farms.

The utilisation and economics of the products of the biogas workers, i.e. the biogas and the sludge are discussed in Part III. Special mention may be made of the sludge-conditioning technique developed by Maya Farms to utilise the large volume of sludge produced.

Large scale biogas system like that of the Maya Farms both facilitates and necessitates integration of other systems with them. This is because the biogas and sludge requirements of such systems may be far in excess of the fuel/fertiliser systems of the farm/parent organisation. The functioning of an integrated biogas system and the potential and economics of the system for rural development together with a glimpse of the status of biogas in various countries is given in Part IV.

MARAMBA, FELIX D. SR. Manila, Maya Farms Div. 1982. xx, 230p. Tables, Photographs.

Biogass Handbook.

As is obvious from the title the document is a ready reference source with a great deal of information on biogas all gathered in one place. It is primarily addressed to the prospective beneficiaries to enable them to intelligently choose between plant designs or to design a new model, as well as for the installtion and optimum use of the plant. The structure, language and style of the Handbook, hence is simple and lucid with the scientific concepts given in a descriptive and less-scientific manner to facilitate understanding by lay persons. The whole book is organised like a text book with nine major sections. The various subsections of each section are given their own headings. This helps put information across, since it gives title to each new area and puts the reader on the same track, and also facilitates ready reference of the document. Another significant feature of this Handbook is that at the end of most chapters a brief definition of the new terms used, and a few questions and problems to be worked out pertaining to the concerned chapter are also given.

HOUSE, David. California, Peace Press, 1981. 203p. Graphs, Tables, Diagrams.

Bio-Gas Plants at the Village Level: Problems and Prospects in Gujarat.

This is a report of the project initiated at the Centre for Management in Agriculture, IIM in collaboration with the Gujarat Agro-Industries Corporation, Ahmedabad. The objective of the project was to look into the working of the entire system including the users, agencies involved in financing, installing and servicing biogas plants from a management perspective. It also examines the economic feasibility of biogas plants. On the basis of the findings, suggestions have been made to strengthen the organisational structure to meet the challenge implied in the Fifth Plan target of installing biogas plants.

MOULIK, T.K. and Srivastava U.K.Ahmedabad IIM. 1975. iii, 149p. Tables, Charts.

Biogas System in India: A Socio-Economic Evaluation. Charts.

The study conducted by IIM, Ahmedabad, for the National Committee on Science and Technology, Govt. of India was undertaken as part of the All India Coordinated Project on Biogas Development. The objective of the study was to provide an in-depth evaluation of the socio-economic factors of the biogas project in India. Specific aspects studied include factors responsible for discontinuation of plant operation, economic evaluation of the costs and benefits of the technology, examining the efficiency of existing organizational network and linkages as a support system for promoting biogas technology in the rural areas etc. The report also includes some suggestions for improvements in managerial and organisational inputs as a means to efficiently implementing the biogas project by the concerned implementing agencies.

MOULIK T. K. and others. Ahmedabad, IIM, 174p. Tables, Charts.

Biogas Technology in the Third World: A multidisciplinary Review.

This document provides a state-of-the-art review of biogas technology and has been prepared in response to the interest in biogas and other rural energy systems shown by a number of Asian reserachers. The book represents a multidisciplinary approach to the rural energy problem and attempts to review the on-going work rather than the champion particular solutions. The first chapter establishes in broad terms the energy options facing rural communities in the Third World and considers in detail just what is known about the technical aspects of biogas production. A microapproach to the social and economic appraisal of rural technologies, which stresses both the need to examine technologies in their social context and the need to compare biogas investments with alternative uses of the resources available in specific rural locations, is presented in the second chapter. The third chapter complements the other two by presenting practical field experience. It is based on an extensive survey of a large number of biogas plants and their supporting infrastructure in India, Thailand, Indonesia, the Philippines, South Korea, and Japan.

BARNETT, Andrew and others. Ottawa, IDRC. 1978. 132p. Tables, Diagrams.

Chinese Biogas Manual: Popularising Technology in the Countryside.

Translated verbatim from the Chinese original, this manual is intended to popularise biogas technology, especially the Chinese model. It presupposes as little education as possible, relying instead on providing basic principles, drawings and plans of plants, methods for Chinese model plant construction. It is the single background reference material used by the Chinese when embarking on biogas projects even when their local soil and water table force them to invent entirely different construction methods.

BUREN, Ariane van ed. London, Intermediate Technology Pub. 1979, 135 p. Diagrams, Tables.

Guidebook on Biogas Development.

The guidebook is based on the recommendations of the Expert Group Meeting on Biogas Development held at Bangkok from June 20 to 26, 1976. It is intented to serve as a guidebook on the practical aspects of small-scale biogas development suitable for use in rural areas, in developing countries, especially those of the ESCAP region.

Topics covered include basic facts about biogas technology, various factors influencing fermentation, a detailed classification of the available plant models, planning installation and operation of plants, uses of biogas and sludge together with a description of the various existing models of stoves and lamps, plant maintenance problems and methods for improving plant performance, a brief review of community plants, as well as system economics. A revised edition of the Guidebook has been brought out in 1985.

U.N. Economic and Social Commission for Asia and the Pacific. Bangkok, ESCAP. 1980 21, 127p. Graphs, Diagram Tables.

Methane : Planning a Digester.

This book was originally set out to supply some knowledge of the anaerobic digestion process for the construction and use of biogas plants as also for the promotion of the technology. The book is not meant as a complete treatise on microbiological and engineering aspects of biogas technology but is rather claimed as a guide to any one contemplating having a digester installed. Especially so in the context of developed countries. The various aspects discussed include a brief introduction to the technology, the basic principles and conditions of anaerobic fermentation, installation, and operation of various plant models, safety considerations, as well as the different uses of biogas and the sludge. The book further gives a fairly detailed description of the processes involved in the reserach, development and promotion of the technology in both developing and developed countries have also been provided. The last chapter is a glimpse into the likely future of the technology and some conclusions.

MEYNELL, PETER-JOHN 2nd rev.ed. Dorset, Prism Press. 1982. 163p. illus. Graphs, Tables.

Methane Production from Agricultural and Domestic Wastes. London, Applied Sc. Pub. 1981. xi, 269p.

A volume of the "Energy from Wastes Series", this work is intended to be of interest to those who have to manage organic waste treatment and disposal, as well as to a wider readership who want to know more about methane production by anaerobic digestion. The book tries to describe the basis of the biological and engineering problems involved in the design and running of plants and how laboratory and pilot plant work in U.K. is now being developed into full scale plants for commercial production of biogas from a variety of feedstock wastes. Mention may be made of the chapters giving good coverage of the microbiology and biochemistry of anaerobic digestion.

HOBSON, P.N. and others London, Applied Sc. Pub. 1981. ix, 269p.

CHAPTER - 17

INSTITUTIONAL RESOURCES

Several institutions including research centres, Departments of National Governments, Voluntary agencies etc. have recently initiated efforts for the research, development and diffusion of biogas technology in developing countries. Information on the biogas related activities of nearly 200 such institutions have been given below.

001

Academia Sinica,
Chengdu Institute of Biology,
Bio-energy Laboratory,
Hwaxi-Campus, Chengdu, Sichuan,
PEOPLE'S REPUBLIC OF CHINA.

Contact Person: Chen Guang-qian

Phone: 27941-436

Gram: 0416

Summary of Activities:

Mainly biogas technology research and development activities including metabolism. of the micro-organisms involved in the 2 stages of fermentation, hydrogenic and acidogenic functions of hydrogenic bacteria, isolation and study of the physiological characteristics of Methanococcus mazei Barker etc. (various reactions in fermentation process). Experiments on using Dioscorea zingiberensis, fresh leaf and stem of sweet potato as input, thermophilic fermentation of horse and cow manure, methods of increasing the yield and quality of biogas in rural settings etc. were taken up. The biogas programme of Lezhi Distillery of Sichuan province was taken as a case study for the techno-economic analysis of Chinese biogas programmes.

Activities Planned

Apart from continuing studies on the anaerobic bacteria, it is planned to design and demonstrate a New Energy Village in Chengdu plain. Designing new plant models and study of the anaerobic photosynthetic technology and its applications will be taken up. It is planned to have a station for generating electricity from biogas.

002

Action for Food Production (AFPRO),
25/1A, Institutional Area
Dankha Road, D-Block,
Janakpuri, New Delhi-110 058.

Contact Person: Mr. J.B. Singh

Phone: 667445, 660319

Gram: AFPRO ND-110016

Summary of Activities

In 1980 AFPRO launched a pilot project on the demonstration of Janata Model plants. Several demonstration Janata Model plants were set up under this project. A programme of systematic training of professional masons was launched towards the later part of 1980. Since then AFPRO has trained over 1,000 masons and constructed over 250 plants. This was done at the request and in collaboration with voluntary organisations, government and semi-government agencies and institutes, etc. As a result of these AFPRO has developed capability of over 250 grass root level organisations in spreading biogas programme. A two-week international training programme on low-cost biogas technology was organised by AFPRO in 1981-82 at the request and collaboration of EAO/UNDP.

Activities Planned

1. A package project to implement biogas programmes and involving 60-80 grass-root level organisations has been prepared for the next five year period.

2. Providing trainers training and the training of masons and extension managers and technicians will be continued.

3. Performance evaluation of existing plant models and that of Janata Model community demonstration plants and a review of Janata Model Plant Extension programme will be conducted.

4. Technical advice, developing educational and promotional materials etc.

003

ADI Ltd.,
1115 Regent Street,
P.O. Box 44,
Fredericton, N.B. E3B 4Y2,
CANADA.

Contact Person

Robert C. Landine

Summary of Activities

Assessing the performance of downflow and horizontal flow biogas plants in the treatment of settled sanitary wastewater through both simulated (laboratory) dynamic operating conditions and actual (pilot) operating conditions; developing design criteria related to loadings, hydraulic retention time (HRT), generation, etc., for a full-scale plant, and preparing conceptual designs of a few systems utilizing this treatment process and its economic comparisons with conventional muncipal wastewater treatment systems.

004

Agricultural Tools Research Centre,
Suruchi Campus,
P.O. Box 4.
BARDOLI 394 601,
INDIA.

Contact Person

Mr. Mohan Pharikh
Mr. Rahul Parikh

Phone: 95 and 258

Summary of Activities

A project to render the fixed dome type biogas plants leakproof and also to develop methods for precasting the digester and dome structure to enhance speed of construction and ensure gas leakproof points was undertaken in collaboration with the Civil Engineering Dept. of Sardar Vallabhai Regional Engineering Collage, Surat. The project sponsored by UNICEF has resulted in the design of appropriate RCC mix and methods like addition of concrete super plasticizer to achieve reduction in digestor wall thickness, increased biogas impermeability, cost reduction as well as durability of construction. Providing a stirrer, pipe inlet and a damper for the outlet window have been found to increase plant efficiency.

Also, a new quality control device called Combustible Gas Detector has been introduced to detect even minute gas leakage from the plants or gas pipeline and burners.

Activities Planned

1. It is planned to fabricate biogas digester by cast-in-situ method with new concrete mix design.

2. Also substituting iron bars with different fibres as reinforcement in RCC fixed dome plants is planned.

3. The effect of using certain chemical additives to ferrocement for the construction of digestors and domes.

005

Agricultural University,
Dept. of Water Pollution Control,

Biotechnion,
De Dreijen 12,
6703 BC Wageningen,
THE NETHERLANDS.

Contact Person

G. Lettinga
A.F.M. van Velsen

Phone: 08370-83339

Summary of Activities

Research in the field of biogas production in the Dept. of Water Pollution Control is devoted to on-farm production of biogas using cattle and/or pig manure as feed, as well as to the direct anaerobic treatment of raw domestic sewage and industrial wastes to reduce enviornmental pollution in a simple and inexpensive way and to producee energy from the organic as well.

The research on anaerobic digestion coverss psychrophilic, mesophilic and thermophilic systems. All these three types of processes have their specific potentials for practical application. For on-farm digestion of manure psychrophilic digestion looks very attractive, more than mesophilic digestion, because it is less expensive in investment and it can be combines with manure storage. Thermophilic digestion of manure looks not attractive because of the high investment costs and difficulties in its maintenance.

Ananerobic digestion offers big potentials for direct waste treatment, independent on its strength, its temperature and complexicity. A system of particular interest represents the Upflow Anaerobic Sludge Blanket (UASB) process, which has been developed in cooperation with the industry. Dependent on the temperature of the waste water the UASB-process can be applied under psychrophilic, mesophilic and thermophilic conditions. Emphasis in research is given to clearing up the phenomenon of Sludge granulation, as well as to assess the feasibility of the process for a large variety of waste waters, including raw sewage.

006

M/s. Agriculture Associates,
Station Road,
ALWAR 301 001.
INDIA.

Contact Person : Mr. S.C. Joshi

Phone: 3040

Summary of Activities

1) Installation of 115 biogas plants on turnkey basis ranging from 3 m^3 per day capacity to 35 m^3 per day capacity.

2) Manufacture of gasholders and guidepipes as per KVIC design (350 nos.)

3) Large scale manufacture of high class biogas appliances such as gobar gas/biogas stoves (double, single), biogas lamps (Indoor) biogas water remover etc.

Activities Planned

1. Turnkey biogas plants to be installed @ 500 per year.

2. Manufacture of gasholders and guides to be continued.

3. Planning to manufacture gasholders out of fibre glass.

4. Biogas appliances being manufactured in the brand name of "ANUPAM" Biogas Appliances. Planning to export the ANUPAM Biogas Appliances to other countries in near future.

007

Agro Pumpsets & Implements Ltd.,
10-2-317/3, Vijayanagar Colony,
HYDERABAD 500 457.
INDIA.

Contact Person: Sri V. Bhaktavatsalam

Phone: 37547

Gram: AGRO PUMPS

Telex: 0155-577

Summary of Activities

APIL is a nodal agency for the implementation of National Project on Biogas Development for the state of Andhra Pradesh. Fixed dome and floating drum models are being propagated. Construction of plants is done through the following three-tier system-voluntary agencies and contractors for bulk construction, self-employed rate contract biogas technicians, and regular salaried biogas technicians.

Over 3,200 plants have been constructed through APIL. Besides, a number of training courses for masons and women's training courses were held. Publication of books in the local language and production of audio-visual materials also form part of APIL activities.

Activities Planned

Contemplating to establish an R & D centre at the Hyderabad for developing new gadgets and for standardisation of various appliances connected with Renewable Energy Programms A consultancy/manufacturing facility is being planned during the VII Five years Plan. The, APIL is preparing to set up Small Scale Integrated Rural Energy Centres and about 75 community/Institutional Biogas Plants.

008

Agropur,
C.P. 6000,
510 Principale,
Granby, Quebec J2G 7G2,
CANADA.

Contact Person: Roeland H. Peters

Summary of Activities

Design and build a unique biogas plant attached to a cheese and whey powder process plant to eliminate 7200 kWh/d of electrical energy consumption required for the dairy and also produce methane gas that will be burned to produce steam at a rate of 700 kg/h. The system will consist of two anaerobic fixed film plants and other peripherals such as a solid screen, lagoons etc. Following successful completion of the start-up program, the plant shall undergo a 40 weeks performance monitoring program.

009

M/s. Ajanta Lime Works,
Ambica Sahi,
Janata Prakasani,
BARIPADA 757 001
Orissa
INDIA.

Contact Person:

Phone: 81

Summary of Activities

A 8 cu.m Janata Biogas Plant has been constructed for domestic purposes. Two Gobar Gas Deluxe Burners (450 litres/hr), a Gobar Gas Angitti Burner (1130 litres/hr) and a biogas lamp have been installed.

Activities Planned

Programme has been set up to build more biogas plants for providing fuel to the boiler.

010

Al-Kamal & Co.,
GPO Box No. 593,
Dhaka 2,
BANGLADESH.

Contact Person: A.R. Kamal

Gram: "KAMALCO" DHAKA
BANGLADESH

Summary of Activities

(R&D and demonstration, education and training institutional linkages, budget, recent publications, future plans, etc.)

Provides consultancy services for the installallation of biogas plants aspect of developing energy self-sufficient villages. Also conducts training courses and technical supervision programmes for construction of family size plants.

A newsletter called Biogas Sangbad is also being published.

Activities Planned

Continuation of the training and consultancy programmes.

A proposal to set up a unit for manufacturing gasholders utilisation devices and other equipments has been submitted to the Bangladesh Small Cottage Industries Corporation for approval. It is also planned to try out low cost plant construction materials for reducing construction cost.

011

Alexandria University
Chemical Engineering Department
Faculty of Engineering
El-Hadara, Alexandria, EGYPT

Contact Person : Dr. Mohamed Hussien A. Megid

Summary of Activities :

Involved in Studies an the Biological conversion of agricultural wastes (crop residues) and industrial wastes. Biogas production using small relatively inexpensive fixed volume digester system, modification of Indian & Chinese type plants an also being studied.

Other ongoing projects inlcude :-

Evaluation of processes of utilizing agro industrial residues for energy ends; Development & application of biogas gassifiers in Egypt; Integrated waste recycling & energy systems; Utilization of rice hulls for energy & white ash etc.

012

"ANUPAM" Biogas Appliances
Agriculture Associates,
Station Road,
ALWAR 301 001,
Rajasthan,
INDIA.

Contact Person: Er. S.G. Joshi

Phone: 3040, 2244

Summary of Activities

Manufacturing and marketing biogas plant parts and utilisation devices like biogas stoves. Over 140 gasholders and central guide pipes were manufactured for KVIC model plants during 1983-84 period. Also around 2000 biogas Double Burner Stoves and chrome plated frame know controls were manufactured. In addition, existing 5 HP and 8 HP diesel engines were converted to dual fuel engines.

A device for measuring the availability of biogas in fixed dome plants has also been developed.

013

Appropriate Technology Development Association,
Post Box No.311,
Gandhi Bhawan,
LUCKNOW 226 001,
INDIA.

Contact Person: Mr. M.M. Hoda.

Phone: 33506

Gram: 'APTECH'

Summary of Activities

Designing, construction and supervision of plants in Lucknow, Patna and neighbouring places. Most of the plants constructed are connected to toilets and are attached to public institutions like hotels, community centres, etc. Plants to use water hyacinth, rotten potatoes etc. have been designed. A plant run on elephant dung has been designed and constructed by ATDA in the Zoological Garden, Lucknow.

Activities Planned

i) Construction of community biogas plants in villages under the Govt. of India scheme.

ii) Designing and constructing various types of plants for institutions.

iii) Extension work in villages.

iv) Further research on the technology.

014

Asian Institute of Technology,
G.P.O. Box 2754,
Bangkok 10501,
THAILAND.

Contact Person: Dr. Chongrak Polprasert

Phone: 523 9300-13

Gram: AIT-Bangkok

Telex: 84276 TH

Summary of Activities

Has developed a fixed-cover ferrocement biogas plant: the digested sludge was fed to fish ponds for the production of algae and fish (Tilapia). This scheme is being planned for implementation at village level in Thailand and southeast Asian countries.

Activities Planned

To implement the above scheme to some selected villages in Thailand and other southeast Asian countries.

015

Asian Institute of Technology
Energy Technology Division
P.O. Box 2754
Bangkok 10501
Thailand

Contact Person : Mr. Wolfgang Tentscher

Phone : 5290-0100 - 13 ext. 2457

Telex : 84276 TH

Summary of Activities :

The biogas project sponsored by GTZ (German Agency for Technical Cooperation, Ltd.) will comprise, Research on digestion of waterhyacinths in lab and pilot scale.

Research on digestion of pig manure by separate digestion of the solid and liquid phase, development of a concept for optimal utilization of biogas and effluent in piggeries also formpact of the project. In addition, Construction of a biogas plant in a piggery in Thailand, and Studies on acceptance of biogas technology in the country have been planned.

016

Asian Institute of Technology,
Environmental Sanitation Information Center,
P.O. Box 2754,
Bangkok 10501,
THAILAND.

Contact Person: Mr. D.M. Tam

Phone: 523-9300-09, 523-9310-13 extn. 387

Gram: AIT BANGKOK

Telex: 84276TH

Summary of Activities

ENSIC which receives financial support from IDRC, attempts initially to cover all types of information related to rural water supply and sanitation, low cost options for disposal and reuse of wastes. Biogas technology is one among the subjects covered by ENSIC.

ENSIC can help researchers and workers in biogas technology by answering technical queries, and assisting them in documentation and reference services.

017

Asian Institute of Technology,
Renewable Energy Resources Information Center (RERIC),
P.O. Box 2754,
Bangkok 10501,
THAILAND.

Contact Person: Dr. J. Valls

Phone: 523-9300-13 Ext. 391

Summary of Activities

RERIC which receives financial support from the Government of Australia, the

Government of France, CIDA, UNESCO and USAID, attempts to answer renewable energy questions which are seen mainly from an "intermediate" or "appropriate" technology point of view. Subjects covered by RERIC are solar energy, wind energy, small-scale hydropower, biomass energy and biogas. Main activities are collecting and disseminating of information; providing reference, referral, and reprographic services; and providing in-service training on information consolidation.

018

Banaras Hindu University,
Institute of Technology,
Dept. of Mechanical Engineering,
VARANASI 221 005.
INDIA.

Contact Person: Prof. B. Haragopala Rao

Phone: 54291-376

Gram: TECHNOLOGY VARANASI

Telex: 0545-208

Summary of Activities

Stability of burners operating on biogas was studied using burners of different diameters. Burning velocity of biogas for various proportions of fuel air mixtures, and temperature distribution in the biogas flames were studied with a view to design burners for effective and efficient utilisation of biogas. Biogas flames were simulated to study the effect of varying proportion of different components on the stability and performance of the burner.

Activities Planned

Study of biogas flame structure and modification to improve the performance and stability of gas burners.

019

The Bharatiya Agro-Industries Foundation (BAIF),
'Kamdhenu',
Senapati Bapat Marg,
POONA 411 016,
INDIA.

Contact Person: Girish G. Sohani

Phone: 52621/2/3

Gram: BAIFON

Telex: 0145-283

Summary of Activities

(R&D and demonstration, education and training institutional linkages, budget, recent publications, future plans, etc.)

BAIF has been operating an institutional biogas plant of 360 m^3/day capacity. Also it conducts training courses in construction of community type and institutional biogas plants.

020

Bio-Gas of Colorado,
5620 Kendall Ct.,
Unit G,
Arvada, CO,
U.S.A.

Contact Person: Susan Schellenbach,
Fred Varani

Phone: (303) 422-4354

Summary of Activities

Biogas Labs., a division of Bio-Gas of Colorado has designed and performed a number of fermentation conditions and biogas production testing programmes for various governmental and industrial customers. Besides providing, consultancy and training services, manufacture, construction and installation of biogas plants/plant parts to projects/firms like Imperial Valley, California Biogas Project, Leefers Farms, University of Missouri, etc. and conducting on-site testing of various organic materials for their biodegradability and methane production, all form part of the activities of the laboratory. all consulting, education and operation and laboratory training programs are written to fit the client's specifications.

Activities Planned

Construction of Naser hog digester and

480-head dairy digester in northern California. Research with wastes from cattle slaughter house continues.

021

BOTE Consultants (P) Ltd.,
6-3-668/9/3, Panjagutta,
HYDERABAD 500 482,
INDIA.

Contact Person: N.A. Naidu

Phone: 227049

Summary of Activities

Provide consultancy services to agencies involved in the implementation of renewable energy projects including biogas in Andhra Pradesh. Also, prepared feasibility reports on the establishment of community/institutional biogas plants and project reports for their construction.

022

Brazil, Govt. of S. Paulo State,
CETESB - Cia. Tech. Environmental Sanitation,
Environmental Technology Superintendent,
Av. Prof. Frederico Hermann Jr., 345
05459-S. Paub - 5P.
BRAZIL.

Contact Person: Dr. A.C. Rossin

Phone: 210-1100 R. 344

Gram: Technology Development

Telex: (011) 22246

Activities Planned

Development of a few biogas plants for small communities as an alternative to treating primary sludge is planned for 1985. The principal objective has been to devise alternative techniques for reducing the cost of sanitation.

023

Bremen Overseas Research and Development Association,
Bahnhofsplatz 13,
2800 Bremen 1,
FEDERAL REPUBLIC OF GERMANY.

Contact Person: Mr. Ulrich Reeps
Ludwig Sasse

Phone: (0421) 31 37 18

Summary of Activities

BORDA activities in India include feasibility study on the spreading of biogas technology in Maharashtra; IRDP including biogas in Pune District in cooperation with UNDARP-Pune; research project on "Fixed dome plant versus floating drum" in cooperation with KGPS in Ahmedabad, Gujarat, etc. Besides BORDA has been installing pilot scale plants in Rwanda, Africa, Mali, W. Africa, Turkey etc. in cooperation with the respective local authorities. Feasibility study of community plants, R&D on low cost gas meters for community plants, etc., are the other projects.

Also, BORDA has organised two International Biogas Workshops: One in 1979 on strategies of implementing Biogas Schemes and another one in 1984 on Community Biogas Plants.

Activities Planned

1. Continuation of above projects.

2. Feasibility study and technical design proposals for Medium sized biogas plants for third world countries.

3. R&D on locally made ferrocement gasholders and PVC timing for fixed dome biogas plants.

024

British Anaerobic and Biomass Association Ltd.,
The White House,
Little Bedwyn,
Marlborough, Wilts, SN8 3 JP
ENGLAND.

Contact Person: Mr. P.J. Meynell
Dr. J. Coombs

Phone: Marlborough (0672) 870321

Summary of Activities

The major interest in biogas technology is in the production of biogas from agricultural wastes, sewage, industrial wastes and landfill of domestic wastes. Regular meetings on particular aspects of biogas technology, are organised.

BABA has produced a Code of Practice on Safety in and around biogas plants which undergoes periodic reviews in the light of new experience. They have carried out 2 consultancies, one a survey of U.K. digesters on behalf of the EEC and the second a study of biogas scrubbing on behalf of the U.K. Department of Energy.

BABA acts as the link between the industry, universities and the Government in promoting biomass energy and as an information source and point of contact for both commercial and technical enquiries.

Activities Planned

Continue activities with further meetings and consultancies as appropriate.

025

Buildquick Construction Co.,
Shubhlaxmi Shipping Center,
Station Road,
ANAND 388 001.
Gujarat,
INDIA.

Contact Person: Paresh P. Thakar

Phone: 3919

Summary of Activities

Undertakes construction of biogas plants in Gujarat, India. The nature of work executed so far has been the construction of KVIC model biogas digester and gasholder of sizes ranging from 60 m^3-100 m^3. Both horizontal and vertical models KVIC plants have been constructed.

Activities Planned

At present, an offer for turnkey execution of 13 community biogas plants in the Mehsana District of Gujarat has been submitted to Gujarat Energy Development Agency. This offer includes laying out pipelines piping the biogas to use points.

026

CAMPEX Semillas Baer,
Fundo El Encanto,
Casilla 943,
Gorbea,
CHILE.

Contact Person: Hans Heufelder

Phone: 15 (Gorbea)

Gram: CAMPEX Casilla 943 Gorbea/Chile
Telex: 67011 BOOTH CL

Summary of Activities

Several projects of applying biogas systems on farms, especially those using pig manure arfe being studied. Main problem, up to now, has been distance between manure production and housing facilities of people. Biogas could easily be produced near cowsheds and pig raising facilities, but residential areas being at least a few hundred metres away from the cattlesheds/pig sties, gas distribution creates problems.

Activities Planned

At least one project, using pig manure connected to a small factory of conserved meat seems to turn out practicable, but here again, transportation of biogas is difficult.

027

Canada, National Research Council,
Biological Fuels Laboratory,
Div. of Biological Sciences,
Rideau Falls Building,
Ottawa, Ont. KIA 0R6,
CANADA.

Contact Person: L. Van den Berg

Phone: (613) 992-3310

Summary of Activities

Evaluation of downflow anaerobic fixed film plants in terms of performance, methane production and pollution removal potential of citric acid waste, fish processing waste, dairy waste, masonite processing waste, pulping waste and stillage waste and to evaluate commercial film supports.

Activities Planned

Commercial scale systems are under construction.

028

Canada, National Research Council,
Div. of Biological Sciences,
100 Sussex Drive,
Ottawa, Ontario KIA 0R6,
CANADA.

Contact Person: K.J. Kennedy
L. van den Berg

Summary of Activities

Detailed studies on fixed film reactors are now underway and involve a detailed look at film development, a study of ecological developments in the film, and precise measurements of mixing in single and multichannel reactors, in relation to reactor performance. Mathematical models to describe and predict reactor performance are being developed and localization of acid and methane production has been demonstrated. The work will continue to increase the understanding of fixed film reactors and to assist in developing improved reactors and assessing performance of other reactors such as the upflow sludge blanket reactor. The latter reactor was studied in some detail and is also being installed now commercially in Canada. A project to develop a microcomputer package suitable for industrial use and capable of controlling reactors under most operating conditions and of alerting operators of problems outside its control is in progress. The computer control system is intended to alleviate the need for analytical equipment and trained staff for controlling rapid methane production.

Activities Planned

The computer programme is being further modified and tested under contract with the Manitoba Research Council to arrive at a commercially useful prototype package. The prototype will be tested in the mobile reactor in the Maritimes.

029

Canada, National Research Council,
Rideau Falls Laboratory,
Sussex Drive,
Ottawa, Ontario KIA 0 R6,
CANADA.

Contact Person: L. van den Berg

Phone: (613) 992-3310

Summary of Activities

Evaluate and adapt the anaerobic upflow sludge blanket plant originally developed in the Netherlands for mostly soluble wastes, for Canadian wastes and conditions. The work may lead to full-scale application.

030

Caribbean Development Bank,
Technology & Energy Unit,
P.O. Box 408,
Wildey,
St. Michael,
Barbados,
WEST INDIES

Contact Person: Jerome O.R. Singh

Phone: 809-426-1152

Gram: "CARIBANK" BARBADOS

Telex: WB 2287

Summary of Activities

Demonstrating the use of biogas technology for improvement in sanitation, pollution control, energy production and the production of biofertiliser in rural communities, small farms/households, medium farms, large farms and agro-industrial plants.

Demonstration programmes and running training workshops are being held for the purpose. Linkages exist through the Ministries of Agriculture, Agricultural Extension Services, farmers organisations and rural community groups. The 1984/1985 budget for Training Workshops and Building Demonstration Systems is US $200,000. Technical Assistance in the form of 72 man months of effort is being provided for this project.

Systems ranging in size from 10 m to 200 m have been built in three countries and during 1985, work will begin in other countries in the Caribbean where possibilities for commercialisation have been identified.

TEU publishes a quarterly newsletter.

031

Central American Research Institute for Industry.
Applied Research Division,
P.O. Box 1552,
Guatemala City,
GUATEMALA.

Contact Person: Jose Francisco Calzada

Phone: 31 06 31

Telex: 5312 IC AITI-GU

Summary of Activities

A project on the anaerobic fermentation of coffee pulp juice was completed during 1979-82. Batch and continuous systems were assayed using coffee pulp juice and in the continuous system, two different methods were explored - a single phase, and a two-phase process.

A second project for energy and fertiliser production from coffee wastes like coffee pulp (skin and mesocarp) and waste waters from washing is in progress. Two digester designs - the up-flow Anaerobic Sludge Blanket (UASB) and a sponge reactor packed with polyurethane foam - are being tested. A small pilot plant (1 m^3) installed as mobile unit is under construction to test and demonstrate the process.

Activities Planned

- Utilization of wastewaters from the washing of the beans.
- Ethanol production previous to the anaerobic digestion.
- Further studies on the colonisation of polyurethane sponges by adapted microbial populations.
- Final polishing of discharges.

032

Central Institute of Agricultural Engineering,
Nabi-bagh,
Berasia Road,
BHOPAL 462 010.
INDIA.

Contact Person: Director

Phone: 63618, 75171, 74535

Gram: KRIYANTRA BHOPAL

Telex: 0705-273

Summary of Activities

1. Performance evaluation of a 3 m^3 Janata Biogas Plant and a 6 m^3 Indian Model Plant was conducted.
2. A simple and low-cost moisture trap has been designed and incorporated in the existing plant designs.
3. A plant intended to run on night has been designed.
4. Provided construction training to masons and constructed about six plants in the nearby villages as part of biogas extension work. Plant design details have been provided to about 40 individuals/organisations.

Activities Planned

Designing an economic biogas plant through size reduction and use of alternate construction materials, performance evaluation of plants run on alternate feed materials and a study of the socio-economic constraints in the extension of the technology etc. are planned. Testing and designing of dual fuel engines using biogas and development of means of transportation of biogas will also be taken up.

033

Central Mechanical Engineering Research Institute,
Mahatma Gandhi Avenue,
DURGAPUR 713 209.
West Bengal,
INDIA.

Contact Person: Dr. B. B. Bansal
Dr. B. R. Guha

Phone: 2261-2262 (PBX)

Gram: MECHSEARCH

Telex: DG P 213

Summary of Activities.

Conducted in laboratory scale and prototype scale experiments on the use of water hyacinth for biogas production. Results have shown that biogas generated from chopped or crushed water hyacinth contains about 52-55% methane and that the sludge contains 2.05% of nitrogen, 2.5% of K_2O and 1.1.% of P_2O_5. Due to its fibrous nature and moisture retention capacity, the sludge is found to be a good soil conditioner also. Field trials using a RCC fixed dome gasholder model have shown difficulties due to gas leak by pressure build-up. Consequently, a floating drum model plant has been developed and awaits field trials.

CMERI has also taken up a project sponsored by Burn Standard Co. Ltd., Calcutta, to instal a pilot to handle 500 kg of municipal garbage per day for carrying out studies on biogas generation from municipal solid waste. Laboratory scale biogas generation rate studies have been conducted by using unblended material in a batchfed digester under ambient temperature conditions (29-31° C). The results obtained so far show promise.

034

Centre de Recherche Industrielle du Quebec,
333 rue Franquet,
C.P. 9038,
Ste-Foy,
Quebec G1V 4C7,
CANADA.

Contact Person: Denis Morrissette.

Summary of Activities.

The Project intends to develop a prototype biogas plant using the advanced systems designs of NRC and the techniques and materials of CRIQ and to establish their costs. Specific programmes included designing a 50-60 m^3 plants, selection of fixed film material, coarse screen for filtering the solids, gas storage and utilisation systems, a control system, etc. A system for solid-liquid separation of the sludge permitting maximum recovery of protiens reviewing the safety regulations, studying the mass-energy also form part of the study.

035

Centre for Agricultural Mechanization and Rural Technology (CAMARTEC),
P.O. Box 764,
Arusha,
TANZANIA.

Contact Person: Frederick Sumaye

Phone: 3594/3666 Arusha Dulmti 48

Gram : ATARU

Telex : 42126 AIRSHIP (CAMARTEC)

Summary of Activities

1. Development of Indian model biogas plants in the villages, institutions etc.
2. Follow up of the units to monitor their effectiveness.
3. Development of ferrocement gasholder.

Activities Planned

1. Biogas extension program to be intensified throughout the country.

2. Development of other plant models.

3. More research into feed materials and effect of temperature changes on fermentation.

036

Centre for Technology Alternatives for Rural Areas,
Mechanical Engg. Dept.,
Indian Institute of Technology,
Powai,
BOMBAY 400 076,
INDIA.

Contact Person: Prof. A.W. Date

Summary of Activities

Documentation of renewable energy sources, education and research in rural energy problems and solutions.

037

Centre for Water Resources Development & Management (CWRDM),
Kunnamangalam PO,
KOZHIKODE 673 571,
Kerala,
INDIA.

Contact Person: Dr. S.A. Abbasi

Phone: 60364, 63151

Gram: WATRES, KUNNAMANGALAM

Telex: 854-294 CWR IN

Summary of Activities

The focus of research efforts till date has been a generation of biogas from aquatic weeds, with special reference to water fern Salvinia. So far 15 major aquatic weeds and Mimosa sp have been studied as possible input for biogas production. Bench-scale studies followed by large-scale trials have been carried out on the above materials.

Activities Planned

Through a project funded by Department of Non Conventional Energy Sources, Govt. of India, the Centre plans to carry out the studies further and especially work on (a) high-rate plants suitable for large-scale utilization of biomass and (b) low-cost 'domestic' units.

038

Centro de Estudios Fotosinteticosy Bioquimicos (CEFOBI),
Suipacha 531,
2000 Rosario,
ARGENTINA.

Contact Person: Dr. Ruben H. Vallejos

Phone: (041)38-1480

Telex: 41817 CIROS AR

Summary of Activities

The main efforts in research have been focused on the selection of biomass suitable for biogas production. Aquatic weeds and dairy cow manure were regarded as the most promising feed materials, and the following projects are in development:

1) Water Hyacinth:

Anaerobic fermentation of water hyacinth has been performed in bench digesters with high efficiency. A pilot scale plant (1,200 l) is working in a semicontinuous mode (daily feeding) for mesophilic digestion since February 1982. The sludge, after drying has been evaluated for its potential as fertiliser and it was found that it has a good capacity for improving physical and chemical properties of soils.

2) Cow Manure:

Calculations on the quantity and quality of cow dung available, gas yield, and analysis of design of plants for two medium sized dairies are in progress.

Activities Planned

Anaerobic digestion of agroindustrial organic waste will be studied in addition to the research currently in development.

039

Ceylon Electricity Board,
Energy Unit,
P.O. Box 540,
Sir Chittampalam A. Gardiner Mawatha,
Colombo 2,
SRI LANKA.

Contact Person: Mr. B.P. Sepalage

Phone: 28801

Gram: KILOWAT-CE

Telex: 21368 CE

Summary of Activities

17 biogas plants were installed in rural schools for use in Science Laboratories 25 houses were provided with electricity generated from a 7.5 KVA generator run by biogas in a remote village called Swodagama in the Hambantota District in the Southern Province. 40 more households were supplied with electricity since 1980 from the ongoing scheme of the Rural Energy project in the Pattiyapola Village, Hambantota district, where a 37.5 KVA generator runs on an engine running on biogas from a large Indian type biogas plant of 3,000 ft^3/day capacity. The generator is at present run about 4 hours a day for lighting.

120 biogas plants of varying capacities from household size (6 m^3) to small industrial size (25 m) were built in rural districts for domestic and other uses. Most of these plants were built on a grant given by the Prime Minister through the Ministry of Local Government Housing & Construction in many of the Model Villages.

Activities Planned

The expansion work on the Rural Energy Centre is planned to provide more houses with electricity by use of biogas and other forms of new and renewable energy sources.

The biogas expansion work in the model village will be continued to provide people who settle in these new houses with a cleaner, safer and more efficient source of energy for lighting and cooking.

040

Ceylon Institute of Scientific & Industrial Research,
363, Bauddhaloka Mawatha,
Colombo 7,
SRI LANKA.

Contact Person: Dr. Saman P. Amarakone

Phone: 93807

Gram: CISIR

Summary of Activities

Alternative Substrates:

A variety of substrates have been tried out for the production of biogas. They include water plants (Eichornia, Salvinia), grasses (Panicum maximum), cannary wastes (pineapple peel, passion fruit peel), animal dung (cattle dung, pig dung).

SCP Production from Slurry and CO_2:

The sludge has been made use of for growing algae with a view to producing animal feed. The CO_2 fraction of the biogas is used to increase the yield of the algae.

Activities Planned

Production of SCP from sludge, optimization of the parameters.

041

Chekiang Agricultural University,
Laboratory of Biomass Energy,
Hangchow,
Chekiang,
PEOPLE'S REPUBLIC OF CHINA.

Contact Person: Tse-shu Chien

Phone: 42605

Gram: 2418

Summary of Activities

Studies on the methanogenic bacteria, their isolation, cultivation, physiology, biochemistry and ecology etc.

Separate programmes for biogas production in the rural areas and biogas production and waste treatment in the urban areas.

Activities Planned

Continuation of the above programmes.

042

Chinese Academy of Sciences,
Guangzhou Institute of Energy Conversion,
81, Martyrs' Road, C./P.O. Box 1254,
Guangzhou,
CHINA 510027.

Contact Person: Li Nianguo
Chen Zepeng

Phone: 75600x349-365

Gram: 0508 (Guangzhou)

Summary of Activities

In 1974 the Institute established the first pilot power station in China using biogas from anaerobic digestion of human excreta. Since then, some other plants have been set up in various facilities like slaughter-houses, etc.

On the basis of laboratory scale experiments, biogas has been integrated with solar energy in the demonstration of a new energy village. In industrial application biogas energy recovery is linked up with wastewater disposal in brewery distillery, alcohol distillate, paper pulp black liquid and furfuraldehyde sewage from workshops in sugar refineries, as well as wastes from processing of rubber and monosodium bicarbonate. Laboratory tests on microbial kinetics in these respects are under way, together with those on two-phase digestion and dry fermentation. For rural application, a model of mono-fuel biogas engine, 12-kW in capacity, was developed by the modification of a 20-HP diesel engine. Further various biogas plant models have been studied, ranging from 'Chinese type' water pressure ones to 'red mud plastic' storage bag type low pressure digesters.

Activities Planned

The Institute concentrates on the accelerating gas production rate, through studies on bacteria isolation, additive selection, digester type modification and fermentation technology improvement. Methods to decrease energy cost is also under concern. By the agreement signed with UNU, some researchers from the devloping world are sent to the Institute for training and research on biogas production and utilisation.

043

Colorado State University,
Dept. of Microbiology,
Dept. of Agricultural & Chemical Engg.,
Ft. Collins, CO 80523,
U.S.A.

Contact Person: Dr. Robert P. Tengerdy

Phone: 303-491-6163

Summary of Activities

A two-phase anaerobic digestion process has been developed for the conversion of liquid swine manure and solid cattle manure into animal feed and methane. In the first phase, in an acidogenic fermentation of 2-4 days retention time at 2.5-7.0% dry matter load, 46% of the insoluble organic matter was solubilized mostly as short chain fatty acids. In the second phase, in a methanogenic fermentation of 8.5 days retention time at 4.5% dry matter load the gas production was 1.16 l CH_4/l, day The sludge of this phase is a good animal feed, and the product of the first phase also can be used for additional SCP production in an aerobic yeast fermentation.

Activities Planned

A cooperative work is agreed upon with the University of Technical Sciences, Budapest, Hungary, for improving and expanding on the two phase digestion process.

044

Commonwealth Scientific and Industrial Research Organisation,
Division of Food Research,
P.O. Box 52, North Ryde,
N.S.W. 2113, AUSTRALIA.

Contact Person: Dr. Alan Lane

Phone: 02 887 8333

Telex: AA 23407

Summary of Activities

1. Long-term laboratory trials using a variety of fruit and vegetable processing waste solids as feedstock for anaerobic digestion. Wastes tested so far include cocoa pods, spent coffee grounds, apple press cake, pineapple pressings, reject whole fruit, corn cobs and extracted sugarbeet pulp, etc.

2. Laboratory and pilot scale (25 m^3) trials with UASB digestion of strong liquid wastes (citrus peel press liquor).

3. Laboratory trials with UASB digestion of weak liquid wastes (sultana packing effluent).

Activities Planned

1. Continuation of laboratory trials with UASB digestion of citrus peel press liquor.

2. Factory trials with pilot-scale UASB digestion of weak liquid waster (sultana packing effluent).

045

Companhia De Gas De Sao Paulo (COMGAS),
Rua Augusta 1600,
70 Andar,
01304 Sao Paulo SP,
BRAZIL.

Contact Person: Engo Fernando Antonio Raimundo

Phone: (011) 289-0344

Telex : (011) 21831

Summary of Activities (1980-June 1983)

The Raposo Tavares Landfill gas recovery station has been constructed. This station supplies 240 Nm^3/h of the recovered landfill gas to a nearby industrial concern.

Installation of a high density polyethylene biogas distribution network for supplying biogas for demestic customers for experimental purposes.

A study to estimate the potential of biogas from sewage and garbage in the city of Sao Paulo.

Activities Planned

Development of new biogas recovery projects to Sao Paulo's main landfills.

046

Consultants for Management of Development Programmes bv (CDP),

Achter Clarenburg 25,
3511 JH Utrecht,
THE NETHERLANDS.

Contact Person : Erik Kìjne

Phone : (030) 31 38 65.

Telex : 76358.

Summary of Activities

The CPD is availàble for consultancies on feasibility studies and identification missions regarding biogas implementation programmes. They have published an inventory field study of the state of development of biogas technology in countries like India, Thailand, Indonesia, Singapore, Hong Kong and Taiwan. The study is entitled "Biogas in Asia" and was brought out in 1984.

047

Council for Advancement of Rural Technology
Guru Nanak Foundation Building,
New Mehrauli Road,
NEW DELHI 110 067.
INDIA.

Contact Person: T. Balakrishnan

Phone: 665107

Gram: RURAL TECH

Telex: 61290

Summary of Activities

CART was set up under the Ministry of Rural Development, Govt. of India to act as the national nodal point for coordination of all efforts of development and dissemination of rural technologies for selected sector. The Council provides financial assistance to project for the development of new technologies dissemination of scientific information and transfer of technologies.

048

Delhi Municipal Corporation,
1-Shiv Mandir Marg,
Lajpat Nagar II,
NEW DELHI 110 024.
INDIA.

Contact Person: Mr. Jai Narain

Phones: 621352.

Gram: Lajpat Nagar New Delhi,

Summary of Activities

Biogas produced during the anaerobic digestion of the Sewage/Sullage at the Okhla Sewage Treatment Plant has been piped through a network of 7 kms. of HDPE pipes.

800 gas connections have been provided at a cost of Rs.8.3 lakhs. Net surplus is Rs.2.10 lakhs p.a. The scheme has been very successful.

The 2nd phase of the scheme was started about 2 years ago for providing 10,000 connections at a cost of Rs.130 lakhs. About 50 kms. of HDPE pipelines have already been laid out of which 12 kms. have already been tested and commissioned, about 400 domestic connections have been given. When the scheme is complete, the gross revenue shall be Rs.30 lakhs per year. In about 6 years time, the total investment shall be repaid.

Activities Planned

The gas distribution network of 110 kms. shall be completed. Booster Blowers shall be installed at Okhla Sewage works and 10,000 gas connections shall be energised.

Similar piped gas supply scheme from West Sewage Treatment Plant shall be commissioned and 1,500 domestic gas connections shall be provided.

049

Dharmsinh Desai Institute of Technology,
College Road,
NADIAD 387 001.
INDIA.

Contact Person: Dr. C.M. Ramasamy

Phone: 3354

Gram: DDIT NADIAD

Summary of Activities

Prepared a project report on biogas from agricultural waste.

Activities Planned

It is proposed to construct a biogas plant using agricultural waste as the input.

050

Dynatech R/D Company,
99 ERIE Street,
Cambridge, MA 02139,
U.S.A.

Contact Person: Donald L. Wise.

Phone: 617-868-8050

Telex :92-1483

Summary of Activities

Research and development on anaerobic digestion of agricultural crop residues, cost estimation for fuel gas production from agricultural crop residues via a pre-treatment/digestion process etc.

The various processes used to produce methane from cattle feedlot wastes was evaluated for the U.S. Department of Energy. This study provided a design basis for the large-scale experimental facility which was constructed for DOE, in Bartow, Florida,

051

Egypt, National Research Centre,
Al Tahrir Street,
Dokki, Giza,
Cairo,
EGYPT.

Contact Person: Prof. Dr. Eng. Mohamed M. El Halwagi

Phone: 701211

Gram: Research Cairo

Telex: NAREC UN 94022

Summary of Activities

A project to assess, on a national scale, the technico-socio-economic feasibility of biogas technology for rural areas of Egypt was set up.

While continuing with multidisciplinary R&D work covering the key aspects relating to anaerobic digestion of village organic residues, work centered on the demonstration phase. Three prototype units of the locally-modified, adapted and improved Indian and Chinese types were demonstrated and tested in the NRC extension site. Since early 1981, five family-size units were demonstrated in two villages. One of the units was built for the joint use of two families as a pilot demonstration of community plants.

By March 1983, a 50 cu.m. tunnel type, internally heated and externally housed in a green house plant has been locally designed and constructed in one of the chicken houses of the poultry raising community of 'Shubra Kass' village. Initial performance is very encouraging.

Activities Planned

- Follow-up of all demonstration plants, quantitative assessment of their performance, social and environmental impacts, and economic feasibility.
- Development of new types of plants in the NRC extension site and completing it to be a national training and extension center.
- Hold an International Conference on the "Current State of the Art of Biogas Technology Transfer and Diffusion" in November 1984 in Cairo, Egypt.

052

Environment Canada,
Waste Water Technology Center,
Burlington,
CANADA.

Contact Person: B.E. Jank

Summary of Activities

Under a cooperative project of the Waste Water Technology Center and the National Research Council, a data base for comparison and process design for four plant concepts - the anaerobic filter, anaerobic fluidized bed reactor, UASB model, and fixed film model - will be developed. In the 1st phase, pilot plant studies to evaluate the above models for methane production from industrial and municipal wastes have been conducted. Data from these studies is intended to assess problems associated with scale-up and to establish an adequate information base for full scale process design.

Activities Planned

The 2nd phase of the project will be continued. Development and demonstration of an automated process monitoring and control package for high rate anaerobic reactors and identification of design and operational constraints of the plant for energy production, pollution control and unsteady state operation forms the 2nd phase.

053

Federal University of Ceara,
Nucleus of Non Conventional Energy Sources,
Centro de Ciencias - Campus do Pici,
Caixa Postal 3010,
60,000 Fortaleza - CE,
BRAZIL.

Contact Person: Harbans Lal Arora

Phone: (085) 2233511

Telex: (085) 1732

Summary of Activities

1) A modified Indian type biogas plant suitable for the rocky soil of the Northeast region of Brazil have been developed. About 50 such units with capacities ranging from 10 m^3 to 60 m^3 have been installed in the interior of the state of Ceara.

2) The Chinese model plant has been modified by incorporating

   a) pressure regulator,

   b) a system of automatic outlet for the sludge,

   c) residual biogas collector from the open tank of the plant.

3) An economical model (500 m^3) for treating slop from the pilot plant distillery of 12,000 l/d based on amilaceous materials have been installed.

Activities Planned

Negotiations are in progress with appropriate Government organisations for further R&D work and for expansion of the biogas programme Development of biogas plants to suit small farm residues as well as industrial wastes has been planned.

054

Fermentation Research Institute,
Tsukuba,
Ibaraki 305,
JAPAN.

Contact Person: Kazuhiro Tanaka

Phone:0298-54-6082

Summary of Activities

Studies on the anaerobic treatment of wastewater by anaerobic process and the two-phase anaerobic digestion.

Activities Planned

Continuation of the above programmes.

055

Foundation to Aid Industrial Recovery,
6-3-883/2-3, Panjagutta,

HYDERABAD 500 482,
INDIA.

Contact Person: Mr . T. Sridhar

Gram: FOUNDATION, HYDERABAD

Summary of Activities

The Foundation is involved in the popularisation of Biogas Technology in the state of Andhra Pradesh. It helps villagers in installing biogas plants by establishing necessary contacts with nodal agencies for biogas development, banks giving financial assistance to biogas beneficiaries etc.

Also, it has prepared a Feasibility Report on Integrated Rural Energy Centre for a village near Hyderabad. The first stage in the proposed Integrated Rural Energy Centre in the installation of biogas plants.

Activities Planned

Preparing Approach Paper Biogas Plants for VII Five Year Plan for Andhra Pradesh.

056

G.B. Pant University of Agriculture & Technology,
Dept. of Farm Machinery & Power Engineering,
College of Technology,
PANTNAGAR 263 145.
Dist. Nainital (U.P.)
INDIA.

Contact Person: Dr. Bachchan Singh
D.P. Darmora

Gram: TECHNOLOGY

Summary of Activities

Present activities include the following:

1) Studies on the availability and physical characteristics of dung, engineering parameters of biogas production.

2) Comparative evaluation of drum type and fixed dome type biogas plants with respect to their gas production, gas pressure, plant maintenance etc.

3) Development and performance study of small biogas plants made of alternate materials.

4) Performance tests of spark ignition engines and compression ignition engines fed on raw biogas as well as compression ignition engines fed on scrubbed biogas.

5) Development and testing of a carbon dioxide scrubber.

6) Promotion activities like studies on techno-economic viability and social acceptability of biogas plants, installation of community biogas plants including gas distribution system, preparation of extension bulletins on operation and maintenance of biogas plants, etc.

Activities Planned

Performance evaluation of different biogas burners and lamps is planned. Also, development of economic biogas plants through optimisation of plant dimensions and their performance studies with different organic waste feeds will be undertaken. This is besides design, development and testing of biogas plants suitable for low temperature region (hills). Other areas to be taken up include studies on drying , handling and management of stable slurry.

057

G.V. Olsen Associates,
170 Broadway,
New York, N.Y. 10038,
U.S.A.

Contact Person: Gustav V. Olsen

Phone: (212) 866-5034

Telex: RCA 233405 API UR

Summary of Activities :

G.V. Olsen Associates publishes a monthly abstract journal entitled BIOGAS, which contains abstracts pertaining to methane, anaerobic digestion, gasification/fermentation, new plants and technologies etc.

G.V. Olsen Associates also engages in information research and dissemination on specific topics requested by clients, publishes a monthly newsletter, OLSEN'S AGRIBUSINESS REPORT which also covers biogas, and publishes special studies and reports on biogas and biomass energy.

Activities Planned

- Publication of abstract journals, including BIOGAS MONTHLY UPDATE.
- Information searches, on-line data base literature searches in areas of biomass energy and agribusiness, including biogas.

058

Gadepally Bio Industries,
Regd. Office: Vutla Lane,
Kambham Choulty Street,
RAJAHMUNDRY 533 101.
INDIA.
Bombay Off.: A-105, Prashant Apartments,
Opp. IIT Main Gate
BOMBAY 400 076. INDIA.

Contact Person: Prof. G.S.R. Narasimhamurty

Phone: 582008

Summary of Activities

Feasibility studies of using plant materials, municipal garbage, household and kitchen waste, food waste, paper and cardboard etc. for biogas production have been conducted. The process makes use of the synergistic effect of physical, chemical and bacteriological operations to get higher yields than those obtained by conventional methods of anaerobic digestion. The process has been tested on a working unit for one year on a household size unit. Pilot plant data are collected using canteen waste as raw-material for three months. Technoeconomics of the process have been worked out.

Activities Planned

Collection of pilot plant data, optimisation of process and design variables, study of process dynamics, technoeconimics and setting up of full size commercial units using different materials.

059

Gandhigram Trust,
Gandhigram,
Madurai District,
Tamil Nadu,
PIN 624 302.
INDIA.

Contact Person: Shri V. Padmanabhan.

Phone: 326 Chinnalapatti

Gram: Gandhigram (Madurai)

Summary of Activities

Gandhigram Trust has a Regional Centre in biogas sponsored by the Khadi & Village Industries Commission, Bombay. The purpose of establishing the Regional Centre is to collect data about different designs of biogas plans in existence to evaluate their performance with a view to adopt them to different conditions: climate and otherwise. The following plants have been established:

1. The conventional KVIC and Janata models for control.
2. The latest design of KVIC with lower retention period, a restricted diameter for the mild steel gasholder and attached to a toilet.
3. A modified Chinese model with a spherical bottom and spherical top, and inlet pipe, manhole, etc.
4. Ferrocement plant with or without water seal.
5. Masonry digester with HDPE gasholder.
6. A plant run on night soil, etc.

Activities Planned

It is proposed to design a plant which will be fed with slurry heated by solar energy A study of the level of absorption of pollution in water by water hyacinth and it effect in biogas production will be taken up.

060

Gobar Gas and Khad Utpadan Jojana,
Naya Tola,
MUZAFFARPUR 842 001. Bihar.
INDIA.

Contact Person: Mr. Ram Chandra pd. Sinha

Phone: P.P. 5682

Summary of Activities

72 small and medium size biogas plants have been cosntructed so far. The organisation helped 165 cottage indsutries and individuals to get financial assistance from banks and other agencies for installing biogas plants. A few of the plants have been connected with latrines. As far as motivation and extension is concerned, several training courses, seminars, etc. have been organised.

Activities Planned

The target is to install 150 KVIC model and 200 Janata model plant out of which 76 will be connected to latrines. It is intended to arrange to get 32 sets of solar water heater for raising slurry temperature in winter. It is planned to generate biogas from night soil for lighting purposes. In the area of financial assistance, about 190 beneficiaries have been identified as eligible and in need of financial assistance. Seminars, meetings, etc. will be conducted for motivating the people in adopting biogas technology.

061

Gobar Gas Research & Training Centre,
Ajitmal,
ETAWAH (U.P.)
INDIA.

Contact Person: O.P. Khare

Gram: Gobar Gas

Summary of Activities

Research and Development work in Biogas Technology such as:

1. Alternative source of feed materials other than dung for biogas plant viz. agricultural and forestry wastes, weeds, etc., standardization of gas production identification of parameters for higher biogas yield etc.

2. Developing new low-cost biogas appliances using local materials and increasing the efficiency of different biogas appliances.

3. Design, development and improvement of Janata Biogas Plants.

4. Use of cheaper building materials in the construction of biogas plants.

5. Developing cheaper techniques for transportation and utilization of sludge in the field.

Community Biogas Plants:

Various Community Biogas Plants have been installed and some other plants are under construction in the different parts of the country, viz. Kashipur (Nainital Dist., U.P.), Dolwali (Dehra Dun, U.P.), Jainpur (Bulandshar, U.P.), Bani (Pantnagar, U.P.).

Activities Planned

1. Improving the Janata Model plant to increase efficiency, reduce cost and Retention Time.

2. Use of solar energy for raising digestor temperature in winter.

3. Developing low-cost and more efficient biogas appliances.

4. Studies on use of sludge as fertiliser by comparing it with compost and chemical fertilisers.

062

Gobar Gas Tatha Krishi Yantra Vikash (P) Ltd.,
R&D,
Butwal, Rupendehi,
Lumbini Zone,
NEPAL.

Contact Person: Govinda Prasad Devkota

Phone: 137

Gram: Gobar Gas Comp.

Summary of Activities

R&D activities like biogas production from cattle manure, pig manure, night soil, plant wastes such as banana, ipomea sps, water hyacinth etc.; methods for maximizing gas production like use of compost for heat generation, plant insulation with rice husk or rice straw, utilisation of heat exchangers, improvements in gas appliances like double chula, main gas valve, gas meter, manometer etc., low-cost plants using brick-mortar or mud domes, testing the manurial value of the slurryon wheat and maize. etc.

Activities Planned

1. Use of alternative feeds such as straw, maize stalk and Eupatorium sps.
2. Development of various designs of biogas plants such as stretched dome design or modified tunnel design.
3. Study of sludge and its impact on the production of crops (continued).
4. Experiment of biogas appliances (continued).
5. Study of engine operation by biogas.

063

Gram Vikas Kendra, Jamshedpur,
Vikas Manzil, (M/53), TELCO Town,
JAMSHEDPUR 831 004,
Dist. Singhbhum,
BIHAR.

Contact Person: Shri H.S. Varma

Phone: 23959, 23141/Extn. 34

Summary of Activities

Development of new technologies such as biogas plants, windmills etc., among other social development programmes.

064

Haryana Agricultural University,
Dept. of Microbiology,
HISSAR 125 004.
INDIA.

Contact Person: Dr. P. Tauro
Dr. M.K. Jain

Phone: 3721 Extn. 292

Gram: Microbiology Agri Varsity Hissar

Summary of Activities

The Department is involved primarily in understanding the various biochemical and microbiological processes that occur in small biogas plants. A comparative study of batch digestors and a continuously operated (daily fed) digestors has been completed. Studies to increase the level of acetate have been carried out and it is found that the level can be slightly improved by 24-48 hour predigestion of the waste before feeding. Microbiological studies have revealed that Clostridia constitute about 10% of the bacterial population in the digestors are analysed for their hydrolytic activities.

Studies to evaluate the use of saline water, reduction of the retention period, increasing the solid water ratio and recycling of slurry etc. have been carried out.

Activities Planned

The biochemical and microbiological studies with the daily fed plants will continue with the eventual objective of improving gas production.

065

Himachal Pradesh Krishi Vishva Vidyalaya,
Palampur 176 062,
INDIA.

Contact Person: Dr. Anjan K. Kalia

Phone: 206

Gram: HIMKRISHI

Summary of Activities

Under the All India Coordinated Project on Renewable Energy Sources, a study was undertaken to see the comparative efficiency of various models of biogas plants under cold climatic conditions and to modify these designs for this region. The kinetics of biogas production from Lantana camara and Ageratum to use them as substitutes of cattle dung for biogas production were also studied. Chemical characterisation of the different feed stocks and the manure obtained after their anaerobic decomposition were also undertaken.

Activities Planned

It is planned to set up a 85 m^3 thermally insulated solar heated biogas plant and to see its efficiency in winter months. Also, there are plans to develop a biogas plant run only on Lantana camara, as well as to determine the dead space in the existing biogas plant models.

066

India, Council & Scientific and Industrial Research,
Regional Research Laboratory,
Jorhat 785 006,
Assam,
INDIA.

Contact Person: Dr. H.D. Singh
Dr. K.R. Pillai
Dr. B.G. Unni

Phone: 315

Gram: RESEARCH, JORHAT

Telex: 0287-204 Jorhat

Summary of Activities

A domestic size (2-5 m^3 gas/day) biogas production system to digest sugarcane press mud has been developed. The digester is based on the design proposed by ASTRA, I.I.Sc., Bangalore, with some modifications. Operational parameters for the production of 0.5 vol. biogas per digester vol. per day have been worked out. A pilot plant of 10 m^3 working volume has been in operation for more than one year producing 5 m^3 biogas/day containing 65-81% methane at a feed loading rate of 1-2 kg volatile solid/m^3/day. In winter months, though the ambient temperature went down to 7°C, the digester temperature was maintained at 17°-22°C producing an average of 5 m^3 gas/day. For the same loading rate, biogas productivity in summer season (digester temperature 25°-30°C) was nearly double that of in winter season (17°-22°C).

067

India, Council of Scientific & Industrial Research,
Regional Research Laboratory,
Industrial Estate P.O.,
TRIVANDRUM 695 019,
Kerala,
INDIA.

Contact Person: Dr. P.N. Mohandas

Phone: 3371

Gram: CONSEARCH, TRIVANDRUM 19

Telex: 0884-232

Summary of Activities

Biogas production from a mixture of coconut pith and cowdung was studied. When coconut pith was mixed with cowdung the rate of biogas production was found to increase.

Various parameters like optimum solid content, optimum pith to cowdung ratio, nature of pretreatment for the pith etc. for optimum gas production from coconut pith was determined. Pilot plant scale studies using coconut pith cowdung mixture have given satisfactory results. Biogas production from a mixture of salvinia species (African Payal) and cowdung was also studied. Some of the conditions affecting biogas production are being investigated.

Activities Planned

Detailed study of parameters effecting biogas production from African payal and cowdung will be studied. Also pilot plant scale study of the biogas production from African Payal and cowdung will be carried out.

068

India, Government of Bihar,
Dept., of Agriculture,
PATNA 800 015.
INDIA.

Contact Person: Dr. H.M. Singh.

Gram: AGRICULTURE

Summary of Activities

Both the flexible gasholder model and the fixed dome model are in use in Bihar. A programme for demonstration of fixed dome models to the scheduled castes and scheduled tribes has been initiated. Fixed dome models are also being installed under the National Project on Biogas Development.

Fixed dome model was introduced during 1981-82 and so far over 2,000 family size plants have been built. Nearly 8,000 floating drum model plants have been installed in Bihar.

M/s. Sulabh International has developed a plant run on night soil based on the fixed dome model.

Activities Planned

State government has projected a target of 5,600 biogas plants for 1983-84 of which 4,000 will be floating dome type and rest fixed dome type.

Overall target for the State during Sixth Plan Period is 25,000 biogas plants.

069

India, Govt. of Karnataka,
Karnataka State Council for Science & Technology,
Indian Institute of Science,
BANGALORE 560 012.
INDIA.

Contact Person: Mr. S. Rajgopalan

Phone: 33370, 31652

Gram: KSCST C/o Science, Bangalore

Summary of Activities

Under the Community Biogas Plant Programme for Pura Village,

1) Two 750 cuft capacity biogas plants were installed and commissioned.

2) 156 low cost burners designed for the project were installed in 78 households through a gas piping system using approximately 1,500 metres long pipelines.

3) Four boys from the village were trained in dung collection, charging of the plant, slurry filtering and distributing sludge to the villagers contributing dung for the plant.

4) Additional gas storage facilities have been installed to avoid gas wastage.

5) Plant operation and optimization work to increase gas production efficiencies is being carried out.

Activities Planned

1. It is planned to installsolar water heating systems to supply hot water to villagers for cooking purposes to reduce energy needs for cooking from biogas.

2. Innovative methods such as glass panelling on top of the biogas plants as solar heating devices, charging dung mixed with hot water, longer retention of slurry to ensure complete digestion etc. are planned to increase biogas production given the constraint of inadequate dung availability.

070

India, Govt. of Karnataka
Rural Development & Cooperation Dept.,
Multistoried Building,
Dr. Ambedkar Road,
BANGALORE 560 001.
INDIA.

Contact Person: Mr. T.Y. Nayaz Ahmed

Phone: 74985

Gram: VIKAS

Summary of Activities

The National Project on biogas development is being implemented in Karnataka State since November 1981. At the field level, all the officers of various development departments are involved. Under this project two biogas models are being promoted, viz., (1) the KVIC model and (2) Fixed R.C.C. dome type biogas plant designed by the University of Agricultural Sciences, Bangalore. To encourage farmers, subsidy is being paid. Loans through the banks, supply of cement required for the construction of biogas plants and services of skilled and trained masons are ensured by the Government.

Since the inception of the National Project on biogas development, nearly 7,000 biogas plants have been constructed in the State.

Activities Planned

The programme will be continued.

071

India, Govt. of Maharashtra,
Rural Development Dept.,
Mantralaya,
BOMBAY 400 032.
INDIA.

Contact Person: Shri V.B. Patil

Phone: 2029646

Gram: ARDIDT

Summary of Activities

The Dept. is involved in the promotion of biogas technology in the State of Maharashtra. During 1983-84, about 21300 biogas plants have been set up by various state agencies as against the target of 6,000 units. Taking into consideration the past performance of the technology and the response being received from the rural farmers, the state has planned to set up 40000 biogas plants every year during the VIIth Plan Period. As regards training programmes, about 300 training courses for village masons and nearly 1000 seminar/training courses for the rural women were planned for the year 1983-84. The training courses are being organised through institutions in the state which are fully conversant with biogas technology.

072

India, Govt. of Orissa,
Directorate of Agriculture & Food Production,
Agricultural Engineering Wing,
Govt. Implement Factory,
Satyanagar, BHUBANESWAR 751 007.
INDIA.

Contact Person: Mr. C.V. Krishna

Phone: 51044

Gram: GOVT. IMPLEMENT FACTORY, BBSR.-7

Summary of Activities

Serves as the nodal department for National Biogas Project in Orissa. Already, around 1,200 plants have been constructed and 340 masons have been trained in plant construction. Both the conventional fixed dome model and the floating drum models have been modified and improved. The Kalinga Biogas Plant is an improvement over the conventional fixed dome model to minimise the use of cement, bricks, chips and sand; a Mini Gobar gas plant which intended to run on dung from 2 heads of cattle to suit households with such low cattle strength, the FRP model which uses Fibre Reinforced Plastic instead of brick masonry, the Rajwa-KVIC model which uses HDPE for the Mild Steel gasholder of KVIC design and LDPE or bamboo strips, angle iron etc. for digester are such modifications introduced in plant designs.

Activities Planned

1. Construction of biogas plants to reach the Sixth Five Year Plan, target of 20,000 plants.

2. Research and development work.

073

India, Govt. Orissa,
Electrical Projects Investigations Circle,
Unit 1,
BHUBANESWAR 751 009,
Orissa,
INDIA.

Contact Person: Er. Kishore Mohan Panigrahi

Phone: 50948

Gram: EPIC

Summary of Activities

Activities include production of biogas from various biomass wastes and use of biogas in dual-fuel engines for power generation. Also assists in the identification and selection of biogas plants.

EPIC also provides consultancy services to Orissa Renewable Energy Development Agency for power production.

074

India, Govt. of Orissa,
Office of the Asst. Agricultural Engineer,
At/P.O. - Baripada,
Dt. Mayurbhanj,
ORISSA.

Contact Person: Mr. N.K. Mohonty

Summary of Activities

Till June 1983, 120 Janata model (Fixed dome type) and 70 KVIC model (Floating drum type) biogas plants have been constructed in the district of Mayurbhanj.

About 60 masons have been trained on construction of Janata model out of which about 30 masons are really engaged in plant construction in different places.

Activities Planned

It is planned to construct 380 numbers more of plants from July 1983 to December 1985 in the district of Mayurbhanj. Local masons will be trained to accelerate the construction programme. It is planned to train more masons on construction of both fixed dome type and floating drum type biogas plants.

075

India, Govt. of Pondicherry,
Agricultural Dept.,
Deputy Director of Agriculture (E&WM),
State Ground Water unit,
Thattancharady,
PONDICHERRY 605 009.
INDIA.

Contact Person: Mr. T.C. Kaliamurthy

Phone: 6245

Summary of Activities

As part of the Biogas Development Programme during the financial year 1982-83, 100 plants have been constructed. During 1983-84 till Sept. 1983, 50 biogas plants have been constructed.

Agricultural Department has conducted four training programmes for the farmers and technicians in places like Pondichery, Karaikal, Mahe etc.

Activities Planned

Target fixed is the construction of 100 biogas plants.

076

India, Govt. of Rajasthan,
Biogas Cell,
Special Schemes Organisation,
Secretariat,
JAIPUR (Rajasthan),
INDIA.

Contact Person: Shri A. Jaiman

Phone: 76979

Summary of Activities

From the year 1980 to June 1983, about 4,321 family size biogas plants have been installed under the National Biogas Project. The work of construction of 7 Community biogas plants is under progress. Besides this, about 59 demonstration plants have been installed, 550 masons have been trained in 23 districts, 100 Panchayat Samiti level and 40 women orientation courses have also been organised.

The Biogas Cell at the State Headquarter is also formulating Commission for Additional Sources of Energy Projects. Uptil now, 17 Community/Institutional biogas plants projects were submitted to DNES, New Delhi. 7 community biogas plants are under construction. Out of these, one plant has been commissioned; the gas will be supplied to the villagers. Biogas Cell has also prepared an Energy Plantation Project for unirrigated area of Rajasthan Canal Project.

Biogas Cell is also undertaking designing and development of new type of biogas plants considering the non-availability of bricks in the western part of Rajasthan. A stone slab biogas plant has also been designed and installed in Jaipur. The plant is under testing since then. The cell has also installed plants with FRP dome and HDPE gas holders. The testing of these plants is under progress.

Activities Planned

The targeted family size biogas plants will be installed. The proposals for community type biogas plants will be submitted to Department of Non-Conventional Energy Sources, New Delhi, for approval. Training for masons, courses for women, etc., will be organised. The construction of community type biogas plant will be started after receipt of sanction from Department of Non-Conventional Energy Sources, New Delhi: Besides this, the biogas programme of districts will be monitored by the Cell.

077

India, Govt. of Rajasthan,
District: Rural Development Agency,
Collectorate,
Chittorgarh,
RAJASTHAN 312 001.
INDIA.

Contact Person: Shri R.K. Saxena
Shri S.N. Baldwa

Phone: 345

Gram: 'Biogas'

Summary of Activities

Installed a number of plants in various districts of Rajasthan. Organised extension programmes and publicity propaganda for biogas technology. Planned the community biogas plants of Sudershan Textiles, Kota, Rajasthan, Vanaspathi Products, Bhilwara; Lalpura and Borawas villages of Rajasthan. A project proposal for community plants in tribal areas is being prepared.

Since July 1982, 59 plants (both KVIC and fixed dome models) have been installed in Chittorgarh and 77 more are under construction. A construction course for masons and an orientation course for women (on practical operation of plants) were conducted.

Activities Planned

Planning to instal about 300 plants (both KVIC and fixed dome models) in Chittorgarh district. Research on using alternate materials like stone patti, stone slabs, lime, HDPE etc., for plant construction as well as possible uses of digested sludge will be undertaken.

078

India Govt. of Tamil Nadu,
Rural Development & Local Administration Dept.,
Directorate of Rural Development,
MADRAS 600 108.
NDIA.

Contact Person: Thiru M. Srinivasan

Phone: 20901

Gram: RURAL

Summary of Activities

The National Biogas Project is implemented in the 8 intensive districts of Tamil Nadu.

During 1981-82, 1,327 plants were constructed as against the target of 3,500 and 5,004 plants as against the target of 5,000 units during 1982-83. During 1983-84 (i.e. upto July 1983) 1,354 plants have been constructed. Further 106 masons were given training, in the construction of biogas units. A number of field level functionaries were also imparted training under this programme. Besides, with a view to create an awareness among rural women folk on maintenance of biogas units 30 one-day training camps (each having 50 participants) were conducted in eight intensive Districts.

Activities Planned

It has been proposed to instal 6,000 plants in Tamil Nadu state during 1983-84 and also to construct one community biogas plant in each District.

10 training courses to village masons and field level functionaries, 30 and one-day training camp to rural women have been proposed for this year.

079

India, Ministry of Energy,
Dept. of Non-Conventional Energy Sources,
Block No.14, CGO Complex,
Lodi Road,
NEW DELHI 110 003.
INDIA.

Contact Person: Dr. K.C. Khandelwal

Phone: 617298
Gram: RENEWABLE
Telex: 31-5318 DNES-

Summary of Activities

As part of the National Biogas project, 25,365 and 57,498 plants respectively, were set up. A target of setting up of 75,000 plants has been fixed for 1983-84.

Activities Planned

i) Organising 150 training courses for village masons, 30 courses for training of trainers, 5 orientation programmes and 500 women education programmes;

ii) Development of procedure for ensuring post-installation and maintenance services; and

iii) Arranging facilities for achieving the targets of setting up of 75,000 biogas plants.

080

Indian Agricultural Research Institute,
Div. of Soil Science & Agril. Chemistry,
NEW DELHI 110 012.
INDIA.

Contact Person: Dr. M.C. Jain

Phones: 581494, 581921

Gram: KRISHIPUSA

Summary of Activities

Studies on biogas production from various organic wastes including different animal excreta, water hyacinth etc. separate or in combination with cow dung. Development of effective and efficient method of handling and disposal of residual sludge.

Development of low cost and efficient burners for biogas, service holder cum pressure regulator for drumless biogas plants. etc.
Installation of biogas plants (small, medium and community type) in villages for studying the technical, social, economic problems related with them.

Improvement in the existing designs and development of new designs, keeping in view the cost reduction, post-installation problems and efficiency of biogas production.

Activities Planned

Critical evaluation of various plant models and developing methods for reducing Retention Time and thereby increasing plant capacity.

081

Indian Council of Agricultural Research,
Cotton Technological Research Laboratory,

Matunga,
BOMBAY 400 019.
INDIA.

Contact Person: Dr. V. Sundaram.

Phone: 882 7273 - 7276

Gram: Techsearch

Telex: CTRL 3594

Summary of Activities

Attempts were made at the laboratory to produce biogas from willow-dust. The low density of the material restricted the studies for only batch fermentation. A number of experiments were undertaken at the bench scale to find out the optimum C:N ratios, solid to liquid ratios, pH conditions, etc. for the maximum production of biogas. Based on the laboratory trials, an experimental biogas plant to process 100 kg of willow-dust was designed and fabricated.

Activities Planned

a) Data on the production of biogas from willow-dust will be collected from the pilot plants to be commissioned shortly at Apollo Mills, Bombay, under the 'Operational Research Project' financed by Commission for Additional Sources of Energy (CASE).

b) Work on dry fermentation of willow-dust to minimise water and also to obtain a very good manure.

c) It is also planned to make the process continuous.

082

Indian Institute of Management,
AHMEDABAD 380 015.
INDIA.

Contact Person: Prof. T.K. Moulik

Phone: 450041

Gram: INDINMAN

Telex: 12351 IIM IN

Summary of Activities

1. Completed a comprehensive management information system and control for biogas programme monitoring in India.

2. Completed a project on commercialization and marketing strategy of renewable energy technologies with particular reference to biogas technology.

3. Socio-economic and administrative evaluation of community biogas projects in India is being completed as a National Project.

Activities Planned

1. A Workshop on Community Biogas Projects is to be organised in West Germany in 1984.

2. Setting up integrated Rural Energy Centre in Gujarat as a pilot project is planned.

083

Indian Institute of Technology, Bombay,
Environmental Science and Engineering Group,
Powai,
BOMBAY 400 076.
INDIA.

Contact Person: Dr. P. Khanna.

Phone: 581427, 584141

Gram: TECHNOLOGY

Telex: 011-2385

Summary of Activities

A project on optimal design and mathematical modelling of water hyacinth-based biogas plants has been completed. The project addressed to itself to the task of developing a Diphasic Anerobic Activated Sludge Process for Biogas Production with Alkali Pretreatment and formulation of Dynamic Mathematical Models as a tool for Systematic Optimization and Stuides leading to Cost-Effective Designs for Water Hyacinth Substrate. The Mathematical Models have been validated with experimental data.

084

Indian Institute of Technology, Madras,
Centre for Rural Development,
MADRAS 600 036.
INDIA.

Contact Person: Mr. D. Hariharan

Phone: 415342 Extn. 281

Gram: CEEYARDI CARE TECHNOLOGY MADRAS

Telex: 0-41-7362 IIT M IN

Summary of Activities

As part of the Human Resources Development Project, a new design of masonry biogas plant has been constructed with facilities for measuring temperatures of the slurry at different stages of digestion as also production pressures of the gases and flow measurements. Arrangement has been provided for stirring and for recycling of slurry from the teritiary stage of digestion to the first chamber.

Presently, solar panels are being installed to maintain higher temperatures of the slurry by ciculating hot water in a closed circuit immersed in the slurry.

Activities Planned

1. To study methods of increasing gas production and monitoring biogas production from mixed biomass.

2. Designing a biogas system for handling kitchen and lavatory wastes in an industrial plant employing 5,000 people.

085

Indian Institute of Technology, Madras,
Internal Combustion Engines Laboratory,
Dept. of Mechanical Engineering,
MADRAS 600 036.
INDIA.

Contact Person: Dr. K.V. Gopalakrishnan

Phone: 415342 Extn. 236

Gram: TECHNOLOGY

Telex: TECHMAS-MS (041)7362

Summary of Activities

Developing dual fuel engines (using biogas as the main fuel and diesel oil as the secondary fuel) and spark ignited engines working entirely on biogas.

The effects of various parameters which influence the combustion in biogas dual fuel engines like the air fuel ratio, the compression ratio, the type of combustion chamber and injection timing have been determined.

At present, work on converting a small Enfield Spark ignition engine to work on biogas is in progess. The special feature of these tests is that it is being carried out in the field itself with a pumpset connected to the engine and the torque output measured by a torque meter. To improve the air-gas mixing a special ventury has been introduced in the inlet manifold.

Activities Planned

1. Developing a new type of engine called the Surface Ignition engine, in which the ignition of the fuel takes place from a heated surface. It is planned to test this engine with biogas as the principal fuel in the dual fuel mode.

2. It is also planned to take a project of the cultivation of ocean Kelp as feedstock for biogas generation.

086

Industrial Technology Research Institute,
Energy & Mining Research Service Organization
1, Sec. 1, Fu-Hain S. Road,
Taipei,
TAIWAN (REPUBLIC OF CHINA).

Contact Person: Mr. Ming-I Lee

Phone: 02-7219760

Telex: 19434 ERUTRI

Summary of Activities

A computer program, aimed to predict the reaction and the optimum operation conditions of hog manure digestion has been established lately.

Activities Planned

A demonstration system for treating 7,000 heads of hog is expected to be built.

087

Industrial Technology Research Institute,
Union Chemical Laboratories,
1021 Kwang-Fu Road,
Hsinchu,
TAIWAN, (REPUBLIC OF CHINA).

Contact Person: Mr. Tsu Fu Wang

Phone: 035-713131

Summary of Activities

A revolutionary material, called Red Mud Plastics, was invented by Union Chemical Laboratories in 1967 for biogas plant construction. Over 2,000 family-size (15-20 m^3) and one thousand pilot plant-size (50-150 m^3) RMP biogas plants have been installed all over Taiwan and in several other countries.

Activities Planned

Training courses for hog farm owners; information dissemination; etc.

088

Institute for Industrial Research & Standards,
Biomass Conversion Technical Information Service,
Ballymun Road,
Dublin 9,
IRELAND.

Contact Person: Helen Gahan

Phones: (01) 370101

Gram: "Research, Dublin"

Telex: 25449

Summary of Activities

With the objective of collecting and disseminating information on all aspects of biomass energy, the following publications have been brought out:

1) Biomass Abstracts (6 per annum) which provide current information on all aspects of biomass energy including economics, resources, cultivation techniques, harvesting, materials handling, conversion techniques and the environment;

2) Retrospective Literature Searches (4 per annum) on special aspects of biomass energy.

089

Institute for Storage and Processing of Agricultural Produce (IBVL)
Bornsesteeg 59.
P.O. Box 18.
6700 AA WAGENINGEN
The Netherlands.

Contact Person : drs. Berend A. Rijkens

Phone : 08370 - 19043

Summary of Activities :

In addition to the R&D concerning the storage and (industrial) processing of crops, the Institute investigates the processing and treatment of byproducts, solid wastes and waste water. Specific know how has been acquired in anaerobic processing of solid wastes into biogas and compost, and the Institute is prepared for consultancy, engineering and adaptive development work in cooperation with other partners.

For solid waste a novel, patented, two-phase anaerobic digestion process has been developed, consisting of a batchwise hydrolysis (liquefaction) of the solid matter in a reactor(R) under continuous percolation with water. The leachate, containing mainly dissolved volatile fatty acids (vfa), is treated in a conventional UASB reactor (R_2), at a high specific capacity, while the treated water is recycled to the R. Depending on the composition (the degradability) of the raw material a breakdown of 50 to 80% of the solid matter is achieved in 10 to 14 days, under the evolution of the corresponding amount of biogas. Finally the solid residue, removed from the R_1, is composed (aerobically) in windrows, generally heating themselves up to about 80°C, thus yielding a compost low in pathogens and weed seeds.

For the treatment of waste water of the potato processing industry an adapted and improved Uniflow Anaerobic Sludge Blanket (UASB) process has been developed and large scale installations of this type have been engineered for several industries in the Netherlands.

Activities planned :

- a pilot plant fo the anaerobic digestion of the organic fraction of municipal solid waste (M.S.W.) is being built and will be tested in Bremen (G.F.R.) in cooperation with a local engineering firm.

- A plant for the anaerobic digestion of vegetable wastes (surplus, and rejects) consisting of fruit, tomatoes, vegetables and the like will be developed and built with a capacity of several thousands of tons per year.

- A pilot plant for the anaerobic digestion of onion waste will be developed and built for a processing industry.

090

Institute for Verfahrenstechnik/RWTH Aachen,
Templergraben 55,
D 5100 Aachen,
FEDERAL REPUBLIC OF GERMANY,

Contact Person: Prof. Dr. Ing. R. Rautenhach
Dipl. Ing. M. Schulz

Phones: 0241/80/5470

Telex: 08/32704 thacd

Summary of Activities

Production of biogas from agricultural and industrial wastes covering: theoretical, practical and economic studies: construction of a complete biogas plant for a farm, producing crops, cattle and - by its own distillery - alcohol, measurements on operating biogas plants, and flow and heat transfer of manure.

Activities Planned

- Optimization of the process and its economic analysis

- Anaerobic fermentation in food industry.

091

Institute of Agricultural Science,
Office of Rural Development,
Suweon, Kyeongi Do 170,
REPUBLIC OF KOREA

Contact Person: Dr. Young Dae Park

Phone: (6) 4131-5

Summary of Activities

A batch-fed dry anaerobic biogas plant using coarse crop residues and manure as input was developed in 1981. Efforts are on for popularising the design among Korean farmers. About 900 units have been established so far for demonstration purposes.

Besides, biogas production was studied:

1) to determine gas production rate with different kinds of input materials and

2) to evaluate effect of loading rate, dilution, retention time,

3) to project the amount of alternative energy available from manures.

Activities Planned

Programmes for using different organic wastes, developing digester designs, biogas utilization devices, studies on effect of sludge on plant growth in integrated biogas systems; popularising biogas plants with the cooperation of extension workers etc.

Programmes for using different organic wastes, developing digester designs, biogas utilization devices, effect of sludge on plant growth in an integrated biogas system.

092

Institute of Technology,
Bundesforschungsanstalt fur Landwirtschaft,
Bundesallee 50,
D 3300 Braunschweig,
FEDERAL REPUBLIC OF GERMANY.

Contact Person: Prof. Dr. Ing. Wolfgang Baader

Phones: 0531/596311

Summary of Activities

The project on anaerobic digestion of animal wastes and plant material is divided in the following sections:

1) Evaluation of feed material (bench scale digestion tests with different organic materials, sole and mixed; influence of pretreating);

2) clearing of engineering problems with reference to material flow, heat transfer, process control resulting from high concentrations of coarse solids (investigations by using experimental digesters of different size: 1, 6, 100 m^3, and of different type: vertical, horizontal);

3) definition of integrated biogas-systems, adapted to typical farm conditions (configuration, type and size of the plant, means for handling and utilization of the gas, means for treatment and handling of the sludge;

4) description of the preconditions for the economical and efficient integration of biogas-system into the farm regarding aspects of energy supply, environment protection and recovery of valuable matter.

Activities Planned

The project will be continued.

093

International Association for Rural Development (AIDR),
rue du Commerce 20,
bte 3, 1040 Brussels,
BELGIUM.

Contact Person: Ignace Coussement

Phones: Brussels (02) 512.87.19

Gram: INTERDEVELOPRU

Telex: 62928

Summary of Activities

A series of digesters ranging from 3-100 litres have been installed at the AIDR Experimental Centre in Meux permitting the study of the behaviour of different waste materials during anaerobic fermentation. Several other plants representing a cross-section of sizes, input materials and methods for using biogas are in operation.

A study of the application of the biogas-compost process involving 3 countries (Rwanda, Burundi and Upper Volta) was undertaken in 1981/82.

Hot water collectors have been used to heat certain digesters and trials are underway to fabricate a series of cheap, simplified solar collectors.

Activities Planned

Continuation of the above mentioned projects.

094

International Environmental Consultants,
5233 Dundas Street W.,
Suite 410,
Islington, Ontario M9B 1A6,
CANADA.

Contact Person: B.E. Jank

Summary of Activities

The project proposes to undertake to determine the levels of mixing required to achieve the maximum rates of digestion and a full-scale study on the effects of mixing on digester performance. One of the existing 16.8 m diameter primary digesters in Brantford will be used for the purpose. Initially mixing will be optimized to the normal loading rates of 2 kg/m^3/d. Following this higher loading rates will be employed to quantify the degree of improvement by mixing. The following two groups of parameters will be monitored:

a) indicators of performance: sludge volume, fixed and volatile solids, gas production and gas composition;

b) digester environmental conditions: metals, temperature, pH, total nitrogen, and volatile acids.

095

Jadavpur University,
Food Technology & Biochemical Engg. Dept.,
CALCUTTA 700 032.
INDIA.

Contact Person: Prof. Sunit Mukherjee
Prof. D.N. Ghosh

Summary of Activities

A system design approach has been made in developing a model for generation of biogas wherein the sequence of flora in mixed culture fermentation are segregated in compartments ensuring a near plugflow condition whereby channelling is eliminated and desirable retention time is ensured. A rectangular pilot plant has been installed with a digester capacity of about 50 cu ft. with a retention time of 20 days and feeding rate of 40 kg dung/day, generation of gas (with CH_4 content of 64%) was nearly 40 cft/day. The possibility of clogging is minimum while that of destruction of pathogens is maximum.

Activities Planned

Further trials are being conducted.

096

Jamaica, Scientific Research Council,
Hope Gardens,
P.O. Box 350,
Kingston 6,
Jamaica,
WEST INDIES.

Contact Person: Dr. Al Binger

Phone: 927-4471-4

Telex: "SCIENTIST"

Summary of Activities

Construction and installation of medium size Chinese-model plants at Mona Rehabilitation Centre and Adelphi Cooperative Farm (67 m^3 and 45 m^3 respectively). As part of the OLADE/Government of Jamaica Biogas Technology Programme, 9 family-size plants for catering to domestic energy requirements were installed. These plants are the Chinese, Mexican and Guatemalian designs. A prototype family size plant using six 45 gallon drums has been fabricated. Construction of 2 plants using soil/cement aggregate to suit Jamaican situation and a medium-sized (40 m^3) concrete (reinforced) plant are under progress.

Activities Planned

1. Introduction of Plastic Biogas Plant initially of 2 x 15 m^3 and 1 x 50 m^3 is scheduled for September 1983.

2. Setting up fully equipped biogas laboratory so as to intensify feedstock diversification and sludge utilization programmes.

3. Extension of OLADE/Government of Jamaica Programme by building further 15 family-size and 3 medium-size (above 40 m^3) plants.

097

Japan, Ministry of Agriculture, Forestry and Fisheries,
National Institute of Animal Industrv,

Laboratory of Animal Waste Management,
Tsukuba Norindanchi, P.O. Box. 5,
Ibaraki 305,
JAPAN.

Contact Person: Kiyonori Haga

Phone: 02975-6-8676.

Summary of Activities

Research on anaerobic digestion of animal wastes mostly in terms of animal waste management. The prototype digester in which a submersible pump for both stirring and heating was developed by the laboratory and it was used in pilot plant scale experiments in several Prefecture Livestock Experiment Stations. Extension work is now in progress slowly all over the country.

In 1982, a project "Biomass Conversion Project 1981-1990" coordinated by Ministry of Agriculture, Forestry and Fisheries and the National Institute of Animal Industry was set up.

Activities Planned

The new project "Biomass Conversion Project 1981-1990", intends to develop a system which can be applied to small scale pig farmers (less than 50 pigs raised), to produce energy and fertilizer as well as to control animal wastes.

098

Jyoti Ltd.,
Energy Division,
Tandalja,
VADODARA 391 410.
INDIA.

Contact Person: Dr. B.C. Jain

Phones: 59518/59618

Gram: JYOTIPUMPS BARODA

Telex: 011-2385

Summary of Activities

1. Optimisation of gas induction devices for diesel and petrol engines.
2. Basic combustion studies on biogas.
3. Emissions and thermal performance studies of dual-fuel engines.

Activities Planned

Utilisation of biogas in I.C. Engines either on dual-fuel or on gas operation.

099

Jyoti Solar Energy Institute.
VALLABH VIDYANAGAR 380 120,
INDIA.

Contact Persons: Prof. A.C. Pandya
Dr. G.P. Nagori

Phone: 7004

Gram: JESEEI

Summary of Activities

R&D tasks undertaken are related chiefly to two problems:

(a) use of alternate feedstock materials and (b) designing new plant models to suit the feedstock. Alternate feedstock tried out include banana stem - water hyacinth, eucalyptus leaves, congress grass etc. Studies on biogas generation from centres waste and garden wastes are in progress. As regards plant models, a 10 m^3 biogas plant to use banana stem has already been constructed and another 5 m^3 model for eucalyptus leaves is being installed. Also studies on the effect of parameters like presence of chemicals, pulverisation and others on biogas generation are in progress.

100

Jyoti Switchgears Ltd.,
P.O. Mogar 388 340,
Taluka Anand,
GUJARAT.
INDIA.

Contact Person: Mr. J. C. Kapoor,
Mr. K. N. Padia.

Phone: 290 & 294 (Vasad Exchange)

Gram: JYOTSWITCH VADOD

Telex: 172-236 JSL IN

Summary of Activities.

A Chinese model type pilot-plant of 6 cu.m. capacity was built at company's premises during the month of January 1983. Experiments are being performed on this plant to get maximum gas production by varying various parameters, facilities for which are available at JSL.

To maintain the required temperature in the digester, a tube type heat exchanger is utilised with the use of solar energy.

Activities Planned

Possibility of using banana stem for biogas production will be explored. If necessary, modification in the plant will be done to suit banana stem feeding.

101

Kapur Solar Farms,
Bijwasan Najafgarh Road,
P.O. Kapas Hera,
NEW DELHI 110 037.
INDIA.

Contact Person: Mr. N. V. Iyer.

Phone: 391936/635271.

Summary of Activities.

Completion of installation for integrated energy systems including solar thermal, solar photovoltaic, biogas etc. Development of control systems, optimisation of various constituent parts of the systems and the complete systems. Compilation of data for the last three years.

Activities Planned

Enlargement of the systems, addition of wind and micro-hydel, computer models for design of larger systems.

102

Kasturba Gandhi National Memorial Trust,
Kasturbagram Krishi Kshetra,
Kasturbagram,
INDORE 452 020
INDIA.

Contact Person: Mr. T. G. K. Menon
Mr. R. S. Patel.

Phone: 6747 (Indore)

Gram: Menon, Kasturbagram, Indore.

Summary of Activities

A 2,500 cuft capacity plant is operational without breakdown since January 1970. Biogas produced is used for cooking in 40 families (150 persons) every day; the annual sludge production is equivalent to organic manure worth Rs.80,000/-. A nominal sum of Rs.8-10 is being charged per family per month.

During the last 3 years due to the demonstrative value of the above project and extension work in the villages, more than 2,000 biogas plants were constructed and most of them are working properly. One village named Tillore, which is about 10 km. away from Kasturbagram has already constructed 225 biogas plants during the last year and they may construct another 150 plants during 1983-84.

Activities Planned

To construct a 500 cu. ft. capacity Janata model plant to use toilet wastes from the hostel. To construct models of different types of biogas plants for demonstration and education. To use garbage gas plants in the laboratories of Home Science College at Kasturbagram and Krishi Vigyan Kendra, etc.

103

Kenya Industrial Estates Ltd.,
P.O. Box 78029,
Nairobi,
KENYA.

Contact Person : Mr. Y. Diab.

Phone: 542300

Gram: NAINDEST.

Summary of Activities

The KIE-Renewable Energy Programme was started in July 1982. Its aim is to promote and facilitate local manufacturing of Renewable Energy Products, e.g. windpumps for water lifting, wind converters for power generation, solar warm water heaters, biogas plants and the like.

About half a dozen biogas plants have been installed, most of them of the Indian design under the KIE-Renewable Energy Programme. The immediate aim is to compare performances of different types and test its local acceptability.

Ultimately, the type found most suitable and appropriate to local manufacturing shall be chosen and a programme be chalked out to organize widespread application and to facilitate country-wide production.

104

Khadi & Village Industries Commission,
Gobar Gas Research & Development Centre,
Kora Kendra,
Borivli (West),
BOMBAY - 400 092,
INDIA.

Contact Person: Mr. G. L. Patankar.

Phone: 662485.

Summary of Activities

1. Substitute Material for gasholder :

   a) A nylon reinforcement flexible gasholder which is cheaper by about 50% the cost of mild steel gasholder was developed and it has been kept under observation.

   b) A flexible gasholder made from red mud plastic also gave satisfactory results and its cost is expected to be 1/3 as that of the mild steel gasholder.

2. Testing of gas appliance:

   a) Gas appliances from 31 manufacturers/suppliers were tested and their test report sent to Central Office, of the KVIC.

   b) Few Conversion kits for 5 H.P. diesel engine were also fabricated and supplied to various parties for running their engines on gas.

3. Information on biogas technology:

   a) About 7,000 visitors approached this Centre for live demonstration of biogas plants. They were given necessary information in the matter.

   b) A number of schools also approached this Centre for seeking guidance for their exhibitions on biogas held in Bombay. They were given necessary guidance.

   c) One of thee staff members was also sent to Tanzania as an Expert on biogas under the UNIDO assignment for three months.

105

Kirloskar Oil Engines Ltd.,
13, L. K. Road,
Khadki,
PUNE 411 003,
INDIA.

Contact Person: Mr. M. K. Kulkarni.

Phone: 55341.

Gram: KOEL, PUNE.

Telex: 0145-245

Summary of Activities.

Kirloskar Oil Engines Limited markets biogas dual fuel engines in the range of 3 to 70 kW for agricultural applications such as pumpsets, chaff-cutter, thresher, etc. as well as industrial applications like genset, non-clog pump, slurry pump, etc. Genset ratings vary from 2.5 to 55 kVA with 4% governing guaranteed. Several hundreds of these engines have been working very satisfactorily in the hands of many customers. Small biogas plants, community plants and institutional plants have all been equipped with Kirloskar biogas engines throughout the country.

A diesel substitution of 80% is commercially guaranteed for all Kirloskar biogas engines but depending upon the quality of the biogas, a performance level of 85-92% is possible in individual installations. The biogas requirement is about 0.575 m^3/kWh.

106

Krishi Vigyan Kendra,
HANUMANAMATTI 581 135,
Ranebennur Taluk,
Dharwad-District,
Karnataka,
INDIA.

Contact Person: Mr. M. Chowde Gowda.

Phone: 24

Summary of Activities

In the year 1981, KVK initiated the demonstration of fixed dome type (RCC) Bhagyalaxmi Biogas plants developed by University of Agricultural Sciences, Bangalore. Several demonstration models of this type were set up under jurisdiction of KVK. Several programmes for systematic training of professional, masons and field level extension workers of development departments were organised in the year 1982-83 and 1983-84. This was done at the request and in collaboration with voluntary organisations, State Government and semi Government agencies and other institutions. Literature giving information on fixed dome type biogas technology including construction and maintenance details were also published in regional languages.

Activities Planned

Performance evaluation of small capacity fixed dome type biogas plants to increase efficiency, reduce cost and retention time are planned. Also it is proposed to establish a centre for R&D and training in fixed dome type (RCC) biogas technology. Technical advice, developing educational and professional materials will be continued.

107

Kuratorium fur Technik and Bauwesen in der Landwirtschaft (KTBL).
Bartnigstrabe 49, P. O. Box 120142,
D-6100 Darmstadt 12,
FEDERAL REPUBLIC OF GERMANY,

Contact Person: Dipl. - Ing. Dr. E. Dohne.

Phone: (06151) 7001.

Gram: KTBL, Bartningstr, 49 Darmstadt.

Summary of Activities

In 1982 conducted a Congress on All Biogas-Plants in Germany. Moreover, KTBL is in charge of publishing progress reports on all pilot projects in the field of enrgy conservation and replacement in German agriculture.

Already several books on biogas production and utilization as well as papers on gas storage, co-generation and biogas as tractor fuel, have been published.

Providing advisory services to agricultural administration and farmers, supervising several pilot-scale biogas plants are other activities.

Activities Planned

Continuation of the above programmes.

108

L. G. Balakrishnan and Bros. Ltd.,
India House,
Trichy Road,
COIMBATORE 641 018.
INDIA.

Contact Person: Mr. L. G. Varadaraj.

Phone: 30355.

Gram: CONVEYANCE.

Telex: 855-222

Summary of Activities

Biogas plant with Fibreglass Translucent Dome was installed to study ease of construction, cost and increased gas production. Study still continues.

Activities Planned

Biogas plant of Ferrocement, biogas plant with separate gas storage to reduce construction cost etc. being developed.

109

Livestock Development Institute,
(Pashu Palak Vikas Sansthan),
Near Mata Temple,
Mukharjeenagar,
Kashipur,
Nainital 244 713 (U.P.).
INDIA.

Contact Person: Dr. Jagdish Chandra Gupta.

Phone: P.P. 25.

Summary of Activities

The Institute is providing technical assistance to farmers in the installation of biogas plants. The model being propagated is the KVIC model. However, comparative studies and primary data collection of the performance of both KVIC model and Janata Model plants are also being done.

Activities Planned

Future programme includes the development of an integrated biogas system using aquatic plants, agricultural wastes and cattle dung to produce methane, cattle feed (from sludge) and also fertiliser.

110

McLaren Engineers, Planners & Scientists, Inc.,
320 Adelaide Street South,
London, Ontario N5Z 3L2,
CANADA.

Phone: (613) 995-9671.

Summary of Activities

A 3-year project for developing a design for hog waste treatment including gas storage and scrubbing facility for demonstration and marketing to the hog industry was set up in March 1982. Existing designs will be evaluated in terms of their environmental factors like pH, alkalinity, operational factors like RT, organic loading rate etc. and economic factors for developing a new design. The design thus developed will be installed for monitoring, cost estimation energy, balance and overall treatment efficiency assessment before marketing.

111

Maharashtra Arogya Mandal,
Hadapsar,
PUNE 411 028,
INDIA.

Contact Person: Dr. S. T. Gujar.

Phone: 70350.

Gram: Arogyam

Summary of Activities

The institution has installed 150 biogas plants in different parts of Poona District, major parts being at Narodi, Mahalunga and the tribal area in Ambegaon Taluka in Poona Dist. and several plants in other districts of Maharashtra.

Activities Planned

Technical advise will be provided on demand.

112

Maharashtra Association for the Cultivation of Science Research Institute,
Law College Road,
PUNE 411 004.
INDIA.

Contact Person: Dr. S. H. Godbole
Dr. D. R. Ranade.

Phone: 56357

Gram: MACSCIENCE

Summary of Activities

Studies on the microbiology and other aspects of biogas technology, including isolation and identification of micro-organisms-both methanogenic and non-methanogenic-involved in the production of biogas, possible use of varied biomass for production of biogas, possible degradation of industrial wastes through anaerobic fermentation, different parameters and environmental factors influencing biogas production, etc.

Activities Planned

(a) Anaerobic digestion of industrial and agricultural wastes. (b) Two-stage digestion and definition of stages, (c) Studies on the inter-relationship between methanogenic, cellulolytic and other bacteria, and (d) Anaerobic digestion at elevated temperatures.

113

Malanadu Development Society,
KANJIRAPALLY 686 507, Kerala,
INDIA.

Contact Person : Fr. Mathew Vadakemuryil.

Phone: 718 Kjply.

Gram: EMDIES KANJIRAPALLY.

Summary of Activities

Conducted four trainings in 1981 and 1982 for rural masons in construction of biogas plants, and now completed construction of 33 plants of various sizes. Also published a booklet on biogas plants in the vernacular and engaged a full-time personnel team of four master masons, three masons, and a civil engineer to supervise construction of biogas plants. Demonstration plants have been set up in several villages.

Activities Planned

Construction of atleast 500 plants is proposed within the next period of 28 months. New model biogas plants suitable to a small family will be developed. It is planned to launch a publicity programme, with a view to acquainting the rural Kerala families, with the biogas plants and their numerous advantages.

114

Malaysian Agricultural Research & Development Institute (MARDI).
G.P.O. Box 12301,
Kuala Lumpur 01-02,
MALAYSIA.

Contact Person: Mr. H. K. Ong.

Phone: 356601.

Gram: MARDI, Serdang.

Telex: MA 37115.

Summary of Activities.

A 72 m^3 continuous-fed anaerobic digester using piggery waste was put into operation recently. The digester consists of two chambers and is equipped with manual stirrers. Biogas produced is stored in mild-steel gas holder floating over water in concrete tank (12' 10" high; 10' 8" diameter). Biogas is being used for lighting and firing radiant heaters. Water quality of discharge is further improved over a series of ponds. Water hyacinth is grown in the ponds as tertiary treatment and for feeding back to animals.

115

Manipal Institute of Technology,
MANIPAL 576 119,
INDIA.

Summary of Activities

A project intended to evolve a model of

the biogas plant which will be free of the troubles associated with the existing KVIC and Chinese models, and to find out the suitability of real organic wastes for the production of biogas is almost completed.

116

Manitoba Research Council,
Industrial Technology Centre,
1329 Niakwa Road,
Winnipeg, Manitoba,
R2J 3T4,
CANADA.

Contact Person: Mr. K. E. Thacher.

Summary of Activities

The design development and fabrication of a preliminary prototype control system for a biogas plant by modifying and streamling the experimental software programme developed by NRC in line with the above requirements, evaluating the software using a model set up and inputs varying in accordance with known plant behaviour drawing up specifications for the prototype microprocessor and associated hardware, and fabricating and assembling preliminary prototype controller.

117

Mason Dixon Farms,
1750 Mason Dipon Road,
Gettysburg, Pa. 17325,
U. S. A.

Contact Person: Mr. Richard Waybright.

Phone: 717-334-2854.

Summary of Activities

A plant run on 1000 cow heads producing 778, 564 KWH of electricity from the biogas has been installed. The electricity generated is sufficient to meet the complete needs of the farm. The waste heat from the engine exhaust is recovered to heat the buildings in winter, thus replacing 6 gal of 2 furnace oil per hour. Also another plant which is completely underground with 2 feet of earth on top of it was designed and installed for a neighbouring dairy farm.

Activities Planned

Installations of a digester designed for 90,000 laying hens.

118

Maya Farms Division,
Liberty Flour Mills, Inc.,
Liberty Bldg.,
Pasay Road, Makati, MM,
PHILLIPINES.

Contact Person: Dr. Felix D. Maramba.

Phone: 86-50-11.

Gram: Libflour, Manila.

Summary of Activites

With the expansion of the hog population to 50,000 heads, additional digesters, gasholders and sludge conditioning plants were set up to bring the total biogas works capacity at Maya Farms to 4.250 cu.m. of biogas per day. 75 metric tons of manure are charged daily into the digesters. The sludge conditioning plants recover the sludge solids for recycling as feed material and expose the liquid to sunlight and aeration in shallow lagoons to enhance its value as fertilizer-irrigation water and at the same time control water pollution. The biogas is used as fuel for the industrial cooking and heating in the meat processing plant and for running gas engines which serve as the prime movers for the deepwell pumps, slurry pumps, feedmill machinery, refrigeration systems and electric generators.

Maya Farms also served as consultants to establish biogas works in ten other large livestock farms.

Activities Planned

Additional biogas powered electric generators are being set up to make Maya Farms self-sufficient in power by the end of 1983.

119

Mehsana District Cooperative Milk Producers' Union Ltd.,
Post Box. No.1.
MEHSANA 384 002,

Gujarat,
INDIA.

Contact Person: Mr. M. N. Desai.

Phone: 2201.

Gram: DUDHSAGAR.

Telex: 012-287.

Summary of Activities.

Biogas plants erected in the villages have Primary co-op. Milk Socities in the Mehsana district during the year, and 42 are under construction. All these plants are being used by farm families in the villages and biogas thus produced from cow-dung is utilised for cooking as well as lighting purpose. Some milk producers are even selling biogas for cooking purpose to the neighbouring after making provisions of by pass connection. Again cowdung slurry is utilised as excellent organic manure, awaiting to be a real good humus.

120

Mesoamerican Centre for the Study of Appropriate Technology (CEMAT),
18 calle 22-52 zona 10, Apartado Postal 1160,

Guatemala, Guatemala,
CENTRAL AMERICA.

Contact Person: Dr. Armando Caceres.

Phone: 681007.

Summary of Activities.

CEMAT is a private, non-profit organization working in the Mesoamerican and Caribbean regions to forward economic improvement, technological exchange and social progress in the region. As part of their Bioenergy Programmes, the CEMAT is undertaking experimentation and promotion of small to medium-size biogas plants in the Mesoamerican and the Caribbean Regions.

121

Metangruppen/Bioquest,
Skargardsgatan 4.
S-414 58 Goteborg,
SWEDEN.

Contact Person: Mr. Anders Ellegard.

Phone: Sweden-031/426650.

Summary of Activities

Evaluation of a 100 m^3 full scale biogas plant and 45 m^3 plug flow plant run on dairy cow manure; construction and evaluation of a 400 m^3 expanding volume plant for swine manure; and laboratory scale studies on the use of sewage sludge in plug flow digesters, slaughter-house blood in totally mixed digesters, poultry and laying-hen manure in batch digesters, laying hen manure in totally mixed and plug flow digesters at 25 and 35°C etc. Overseas programmes include participation in the construction of a 100 m^3 biogas plant to use sewage water from a hospital in Zambia, reviewing the biogas scene in developing countries etc.

Activities Planned

Evaluation of high-technology totally mixed plug flow digester for swine manure (MABI, Finland).

Evaluation of conditions for introducing biogas plants in northern Tanzania, in co-operation with the Mission of the Swedish Church and SIDA.

122

Montana State University,
Chemistry Dept.,
Bozeman, Montana 59717,
U. S. A.

Contact Person: Mr. John E. Robbins.

Phone: 406-994-4123.

Summary of Activities

Investigation of the kinetics of volatile acid utilization in digesters that produced 1.28 volumes of CH_4 per volume of digester per day. The digesters were operated on a continuous basis with a 16 day hydraulic retention time in the mesophilic temperature range. In all cases propionate turnover was slower than that of acetate.

Activities Planned

Determining the optimum conditions for acid production from continuous flow anaerobic digestion of waste material.

123

National Dairy Development Board of India,
ANAND 388 001,
INDIA.

Contact Person: Dr. B. K. Chakraborty.

Phone: 3002, 3012.

Gram: DAIRY BOARD.

Telex: 0172/207.

Summary of Activities

1. Community biogas project at the Village Vasua Margia. The project intends to set up a 250 m^3 biogas plant at the village Vasua Margia in Kheda District of Gujarat.

2. Energy self-sufficiency in livestock farms. The NDDB is planning to set up biogas plants attached to its Dairy Development Farms.

Studies on fermentation parameters and effective monitoring of plant performance are also planned.

Activities Planned

Integrated Rural Energy Project an experiment of homogenous integration of various energy sources such as biomass, wind power, solar energy and cattle dung etc. available in the village to meet the energy demand is planned for 1984.

124

National Environmental Engineering Research Institute,
Nehru Marg,
Nagpur 440 020,
INDIA.

Contact Person: Mr. M. V. Srinivasan.

Phone: 26071/Extn. 246.

Gram: NEERI.

Telex: NP 233.

Summary of Activities.

One of the projects taken up by NEERI has been to use water hyacinth as an organic additive and supplemental feed to cow dung digesters. Laboratory experiments were conducted on mixing water hyacinth power to plants run on cow dung and which did not show any improvement in either gas production or increased digestibility of cow dung. Batch digesters operated for 30 days using (a) cow dung, (b) dried water hyacinth powder and (c) green water hyacinth indicated that the gas production was 33% less in the case of dry water hyacinth powder and 33% more for green water hyacinth when compared to cow dung. The effect of addition of green water hyacinth to cow dung at different proportions in the daily fed digesters revealed that green hyacinth alone produced 50% more gas as compared to dung at similar operating conditions. An addition of 25% green water hyacinth to cow dung digester resulted in a 31% increase in gas production.

A 4 m cattle dung biogas plant was erected and commissioned at Burujwada (Saoner Dist.). This plant is based on NEERI design which can utilise night soil. The plant has been functioning without any complaints. The gas is used for cooking while the sludge is used as manure for orange.

125

National Institute of Waste Recycling Technology (NIWART-INDIA).
A-18, Juhu Apartments,
Juhu Road,
BOMBAY 400 049.
INDIA.

Contact Person: Dr. T. M. Paul.

Phone: 543517.

Gram: "Recycling" B'bay-Scz. 400 049.

Summary of Activities

Work Completed

(1) Waste recycling on farms, (2) Rural waste management, including agricultural, animal and human wastes, and (3) Pollution-free septic tank, based on recycling principles.

Work in Progress

1) Urban Waste Management by Recycling Municipal garbage and Domestic wastes

Activities Planned

1. The following industrial wastes to be tried as input
   A) Dairy Wastes
   B) Food Industry Wastes
   C) Other Industry Wastes.

126

National Research Development Corp. of India,
20-22 Zamroodpur Community Centre,
Kailash Colony Extension,
NEW DELHI 110 048.
INDIA.

Contact Person: Dr. Y. Venkatesha
Shri P. Soundarajan.

Phone: 649947.

Gram: NATREDEVCO.

Telex: 031 - 3214.

Summary of Activities

The Corporation has financed the development of mini-milk chilling units operating on biogas in collaboration with the School of Applied Research, Vishram Bagh, Sangli, Maharashtra 416 415.

Two prototypes having a capacity of 500 litres have been designed and fabricated. These units are now undergoing field trials. A prototype unit having a capacity of 1,500 litres is under fabrication. These units would enable farmes in remote areas to preserve milk. This would not only help in boosting milk production but also help in cutting down the cost of collection of milk by reducing the trips of milk vans from two to one per day.

Activities Planned

NRDC is negotiating with Jawaharlal Nehru Technical University, Hyderabad, to finance the seting up of a pilot biogas plant operating on water hyacinth based on the experiments already conducted by them

127

New Zealand, Ministry of Agriculture & Fisheries,
Invermay Agricultural Research Centre,
Private Bag,
Mosgiel,
NEW ZEALAND.

Contact Person: Dr. David J. Stewart.

Phone: Mosgiel 3829.

Gram: Mosgiel 3829

Summary of Activities

Laboratory studies on biogas production from a wide range of crops and farm wastes have been carried out in 20 litres continuous plants.

A 45 m^3 farm-size plant using meat wastes (paunch contents, tissue, blood etc.) weeds like thistles and spoiled grain has been operating on an energy farm. Biogas produced is scrubbed in simple locally designed scrubber. Biogas is used in vehicles and dual fuel tractors.

The use of sludge as fertilizer is being compared with similar quantities of N.P. K. and S.

The energy inputs and outputs from the energy farm have been determined and ways of maximising net energy output identified.

Assistance given to farmers and others in biogas plant installation and use.

Activities Planned

Completion of the conversion of the tractor to diesel/gas operation.

Continuation of operation of energy farm and collection of long-term results from the fertiliser trials with the effluent.

Evaluation of the UASB digestion technology as a second phase for digestion of solid wastes and crops after a primary conventional digestion step.

128

OEKOTOP GmbH,
Gesellschaft fur Angepabte Technologien in Entwicklungsgebieten,
Paul-Lincke-Ufer 41,
1000 Berlin 36, R.F.A.,
FEDERAL REPUBLIC OF GERMANY.

Contact Person: Christian Lempelius

Phone: 030-612 50 20.

Summary of Activities

An Advanced Training Programme on Biogas Technology for German Junior-Experts (FRG, P.R. China, India, Guatemala) was conducted in 1981-82. Work for the installation of a biogas plant (450 m^3) run on cattle feedlot is in progress in Ferkessedougou, Ivory Coast. Other activities include providing technical support and consultancy services, documentation on biogas technology, biogas technology transfer and diffusion programmes, etc.

Activities Planned

1) Construction of several biogas-plants (family size) in francophone Africa.
2) Media-support for the diffusion of biogas technology (research).
3) Technical backstopping and short-term consultancy on all aspects of biogas technology.

129

Oak Ridge National Laboratory.
Chemical Technology Div.,
Post Office Box X,
Oak Ridge, Tennessee 37830,
U. S. A.

Contact Person: Mr. Terrence L. Donaldson.

Phone: (615) 576-4853

Summary of Activities

An anaerobic, upflow (ANFLOW) design which uses fixed films of bacteria in a packed-bed column, is being developed as an energy-conserving waste water treatment process. Development efforts have progressed through a successful two-year feasibility study with a 19 m^3/d system Oak Ridge. Tennessee. Process engineering studies are currently being conducted in Knoxville, Tennessee with a 190 m^3/d ANFLOW pilot plant. Studies with this pilot plant began in August 1981 and will be conducted for a total of 2 years. Comparisons between ANFLOW and conventional wastewater treatment models are being developed.

Activities Planned

The ANFLOW pilot plant will be operated with higher BOD waste waters and at higher hydraulic loading rates.

130

Omega-Alpha Recycling Systems,
Rt.1, Box 51,
Orma, W. Va. 25268,
U. S. A.

Contact Person: Mr. Bob Hamburg.

Phone: 304-655-8662.

Summary of Activities

The objective of OARS' efforts is the development of symbiotically integrated organic recycling/renewable energy systems; the demonstration of small to medium-scale practically operating systems for biologically integrated organic material and nutrient recycling, livestock sanitation and pollution control, animal and human food production, and energy production for both stationary and mobile needs.

Thee Draco I installation, completed in 1980, consists of a 600 cu. ft. Chinese water-pressure biogas plant, a 90 sq. ft. solar greenhouse and an 80 sq.ft. algae aquatic plant pond.

Draco II is composed of two 1400 cu. ft. plant, a 420 sq. ft. greenhouse, and two 300 sq. ft. algae/aquatic plant ponds -- all in passive symbolic relationships. Plant insulation has been increased (over Draco I) to provide year-round operation and higher winter greenhouse temperatures. The ponds have been expanded in area and adjustable gates have been installed to allow adequate control of supernatant flow into the growing channels.

As biological systems, it is expected that several years of operation will be necessary to optimize production from the entire system. Draco I's plant and greenhouse production have increased each year.

Activities Planned

Monitoring of both systems' labour inputs, production and essential parameters will continue for several years. The pond in Draco I has proved too small to accomodate supernatant flow and will be expanded. A small fuel alcohol system will be installed in the Draco II greenhouse to take advantage of further benefits and provide a mobile fuel.

131

PSG College of Technology,
COIMBATORE 641 004.
INDIA.

Contact Person: Principal or The Head of the Dept. of Mechanical Engineering.

Phone: 24177.

Gram: Charity.

Summary of Activities

1. A gobar gas plant of 2.5 m^3/day (KVIC Type) has been installed and used for running SI engines and CI engines (as bifuel engines).
2. An investigation to study the effect of the following variables on biogas generation has been completed in June 1983.
   i) Daily mixing and stirring of slurry as opposed to undisturbed slurry,
   ii) pH. level of the slurry.

Activities Planned

It is planned to construct a fixed volume type of plant and study cost factors.

132

Perennial Energy, Inc.,
P.O. Box 15 Hwy. 181,
Dora, Mo. 65637,
U. S. A.

Contact Person: Mr. Ted Landers.

Phone: (417) 261-2204.

Summary of Activities

Designing plants using cow dung manure, vegetable wastes, thin stillage from ethanol plants, etc., and a complete manure-to-electricity system for a 500 cow dairy farm. Besides several low-cost plants were designed, developed and constructed for low-income farms under the Rural Gasification Project. Several engine-generator cogeneration system have also been designed to run parallel with the utilities.

133

Patel Gas Crafters Pvt. Ltd.,
20, Sai Bazar,
M. G. Road,
Santa Cruz (West),
BOMBAY 400 054.
INDIA.

Contact Person: Mr. Jashbhai J. Patel.

Phone: 614 2501 and 614 0929.

Gram: VALVODBASI

Summary of Activities

Developed a Portable Biogas Container to transport small quantities of biogas for daily use in a village from Community Plant to the consumer, in measured quantities. Also a biogas plant with slurry temperature nearing 35°C using Solar Radiation is being developed. Yet another plant located under the cattle sheds near the farmers' house, where extra space is not available is also installed.

Activities Planned.

It is planned to bring about cost reduction in the installation of biogas plants, by design factors, optimisation of dimesions, and selection of materials. Development of a cheap gas meter on lines provided by BORDA is also being considered besides manufacture and sale of continuously improved biogas appliances.

134

Philippines, Bureau of Animal Industry,
Research Div.,
Albang, Rita Legarda Bldg.,
Sta. Mesa,
Manila,
PHILIPPINES.

Contact Person: Dr. Carolina J. Alviar
Mr. Francisco A. Moog.

Phone: 842-2831.

Summary of Activities

The Biogas ng Barangay was launched by the Philippine Government in 1980. This is a supervised credit scheme wherein farmers, especially livestock raisers can borrow money from financial institutions like Agricultural Credit Administration, Development Bank of the Philippines, etc. to install biogas plants. The most popular plant model adopted is the Taiwan model with floating gasholder. Chinese model is also being tried out recently. A study of the operational status of the plants installed has also been carried out.

Activities Planned

1. Evaluation of biogas technology for animal waste and crop residue management.
2. Use of sludge and effluent water as fertilizer, poultry and swine feed and fish feed.
3. Assisting farmers in plant installation.
4. To organise trainer's training courses, seminars for farms, etc.

135

Philippines Ministry of Energy,
Bureau of Energy Development,
Nonconventional Resources Div.,
Merritt Road, Fort Bonifacio,
Makati, Metro Manila,
PHILIPPINES.

Contact Person: Norberto A. Orcello, Jr.

Phone: 851021 31 local 290/291.

Telex: 22259 PNO PH

Summary of Activities

Under the National Non-conventional Energy Resource Development Programme of the Ministry of Energy, 10 projects on the research, development and demonstration of biogas technology have been set up. Recent emphasis, however has been on the use of feedstock other than animal dung. Also, establishment of commercial size plants attached to large scale piggeries and alcohol. Distilleries is currently being encouraged.

136

Philippines, National Institute of Science and Technology,
Taft Ave., Corner Pedro Gil Sts.,
Manila, R.P. P.O. Box 774,
Manila,
PHILIPPINES.

Contact Person: Ms. Pilar G. Anglo.

Phone: 50-30-41.

Summary of Activities

Two projects - one for the indepth study of the biochemistry and microbiology or biogas production and another one on the use of food processing waste materials as input to biogas plants are in progress. The former involves isolation of strains of micro-organisms from cattle/chicken/hog manure for studying their bio-chemical and physiological characteristics. Food processing wastes being tried out are banana and pineapple pealings, distillery slops, filter press cake and other fruit wastes.

Activities Planned

1. Continuation of other important parameters for improving biogas production and preparation of viable methane starter for shortening RT and improving gas yield.
2. Use of alternate substrate like cassava, cakemeal, pineapple stump wastes, etc.
3. Chemical analysis of slurry before and after digestion and different uses of sludge.
4. Extension programmes.

137

Punjab Agricultural University,
LUDHIANA 141 004.
INDIA.

Contact Person: S.K. Vyas

Phone: 22960 Ext. 259, 278

Gram: AGRIVERSITY, LUDHIANA

Summary of Activities :

At present involved in the engineering aspects of increasing biogas generation. Methods tested include heating and stirring the slurry insulation of digestor etc. Also presently initiated a project on installing community biogas plants in a village in Ludhiana. Another project on the operational research on integrated energy and nutrient supply system has also been initiated.

Activities Planned

1) A study on the anaerobic fermentation of solid waste will be taken up.

2) Other projects planned are investigation of methods for increasing the gas yield in large scale biogas plants as well as the setting up of a Regional Training Centre.

138

Resources Development Institute,
1100 Quarters Area,
Hitkarninagar,
BHOPAL 462 016.
INDIA.

Contact Person: Mr. G.G. Puri
Mr. R.K. Dubey

Phones: 65361

Summary of Activities

Designed and developed diesel engine conversion kit, portable high pressure biogas plant, biogas turbine, welding applications of biogas, clay biogas plant, etc.

Activities Planned

Further developments in biogas turbines and clay biogas plants. Extension of clay biogas plant models.

139

S.K.N. College of Agriculture,
Dept. of Extension Education,
JOBNER 303 328,
Dist. Jaipur (Rajasthan),
INDIA.

Contact Person: Mr. Chaina Ram Sepat

Phones: 35

Gram: Agcol Jobner

Summary of Activities

The Dept. is associated with the demonstration and a popularisation of biogas plants. A number of family size Janata Model Plants have been set up under the project. Practical Training was also provided to masons for construction. An attitude scale of experts and extension agents on biogas plant has been developed. Also, the various constraints in the adoption of biogas plants have been studied and analysed.

Activities Planned

Intends to provide technical guidance to beneficious in the construction of Janata Model plants.

140

S.V. University, College of Engineering,
Environmental Engineering Division,
Dept. of Civil Engineering,
TIRUPATI 517 502. A.P.
INDIA.

Contact Person: Dr. P. Pratapa Mowli

Phones: 2781 Extn. 268

Summary of Activities

A research cum demonstration project was set up in which a low-cost gobar-gas plant for domestic use was developed.

Activities Planned

Research on increasing the methane content in biogas is planned.

141

Sarang Ferrocrete,
P.O. Pen,
Dist. Raigad,
MAHARASHTRA,
INDIA.

Contact Person: Mr. Vishnu Joshi

Phone : 177

Summary of Activities

Development of designs for prefabricated ferrocement digesters based on standard design parameters adopted by Khadi Village Industries Commission.

Activities Planned

1) Design and construction of fixed dome biogas plants.

2) Development of fibre reinforced cement gas holder.

142

Shivsadan Griha Nirman Sahakari Society Ltd.,
S. NO. 192/3,
Industrial Estate,
SANGLI 416416, Maharashtra.
INDIA.

Contact Person: Mr. V.R. Joglekar

Phones: 2216

Gram: GRIHNIRMAN

Summary of Activities

Fabrication, transport and installation of biogas plants, building up of research facilities for biogas development, experimenting on biogas generation from various bio-degradable materials, building up of consultancy services for the development of research and commercial projects of "Waste Water Treatment cum Biogas and Manure Generation Plants" with special emphasis on Water Hyacinth (Eichhornia Crassipe), etc.

Activities Planned

Same as above. Intensive efforts would also be made for producing family size biogas plants at the rate of about 1,000 units per year.

143

Societe D'Etude De L' Environnement SEDE S.A.,

1800-Vevey,
Rue du Midi 33,
SWITZERLAND.

Contact Person: Pierre Bremer

Phone: 021/51 05 15

Summary of Activities

Evaluation of prospects of biogas production in Cuba as part of an FAO-Mission Three 100 m^3/day biogas plants for the Canton de Vaud, Switzerland have been constructed.

144

Sri Lanka, Department of Agriculture,

Peradeniya,
SRI LANKA.

Contact Person: G.K. Upawansa

Phones: 08-88331

Gram: Agriculture

Summary of Activities

The inlet of Chinese type biogas units were modified to accommodate a solar heating device and also modified to avoid water hammer effect during charging the unit.

A lever operated scum breaker is also introduced to plants of low temperature areas. This is operated through the outlet; outlet port too is modified for the purpose. With locally available burners, a clay hearth is also introduced. A lowcost lamp with pressure lamp parts is developed, its gas consumption can be set at 3.5 cubic feet per hour. This is very useful and ideal for small homes.

An extension programme was undertaken in Southern Province of Sri Lanka with a government allocation of Rs.70,000/- (U.S. $3,000/-). 26 plants in 3 villages were established under the programme. The owners were trained in maintenance of plants, usage of biogas and use of sludge in home gardens. Many of them decided to use the sludge on red onion as it was guite profitable.

Under village awakening programme, 57 biogas units were constructed in a model village at Nikaweratiya. All these units are intended to be made into a crop-live-stock-energy integrated system in due course.

Activities Planned

1. Extension of biogas usage in farms.
2. Research on solar heating of slurry.
3. Development of low cost-efficient devices.

145

Sri Lanka, Industrial Development Board,

615, Galle Road,
Katubedda,
Moratuwa
SRI LANKA.

Contact Person : Deputy Director, Engg. Industries Unit, Engg. Division.

Phones: 072-490

Summary of Activities

1. Modification of the Chinese model to suit local conditions. Construction of a few Indian Model plants in school laboratories was also undertaken.

2. Providing services to other Government Departments, and voluntary agencies of Sri Lanka.

3. Construction of small scale and large scale biogas plants (chiefly Chinese Model) for the World Vision International Organisations.

Activities Planned

1. Use of low cost materials to reduce construction cost.

2. Use of water hyacinth for biogas generation.

146

Sri Parasakthi College for Women,
(Via) Tenkasi,
Tirunelveli Dt.,
COURTALLAM 627 802.
Tamil Nadu,

Contact Person: Miss S. Baghirathi

Phones: 2144

Summary of Activities

Under the All India Coordinated Programme of Research on Biogas Technology, a study was undertaken to screen, isolate and enumerate cellulolytic organisms for cellulose degradation. Cowdung, night soil and supplementary wastes like paddy-straw, garbage, water hyacinth, etc. were used. One species of methanogens Methanococcus was isolated in vitro and experiments are being carried out to isolate other species of methanogens for study and testing. Experiments are being done with Diphasic Digesters. Fertilizer values of sludge and percentage of conversion into ammoniacal nitrogen were also determined.

Possibility of using alternate feed materials like sawdust, straw, dead silkworm, garbage, water hyacinth, bagasse, grass, groundnut shell, wastes and dungs of various animals, etc., is being experimented.

Activities Planned

1. Studies on the micro-organisms will be continued.

2. The potential of biogas technology (using various feedstocks) in meeting the energy requirements of the region will be assessed. The effect of innoculating cellulose degrading fungi Tricoderma reesi QM 9414 in the first acid forming stage will be studied.

3. Improving the existing Indian and Janata Designs and use of alternate feed materials and alternate use of sludge will be taken up.

147

Standards & Industrial Research Institute of Malaysia (SIRIM),
P.O. Box 35,
Shah Alam,
Selangor,
MALAYSIA.

Contact Persons : Dr. Mustapha Yusoff
Mr. Badaruddin Baharum
Ms. Chew Thean Yean

Phones: 592601

Gram: SIRIM SEC SHAH ALAM

Telex: MA 38672

Summary of Activities:

R&D on anaerobic mesophilic/thermophilic treatment of palm oil mill effluent in co-operation with local research institutes such as palm oil research institute of Malaysia

(PORIM). The use of biogas for electricity generation is also being studied. A pilot plant (10 m^3) has been in operation for the past 3 years.

Also involved in the promotion of small to medium biogas plants (8-20 m^3) in several states of Malaysia. Plant models adopted are the Indian design and red mud plastic digestors. Large size plants of 127 m^3 capacity are also being installed. The projects are sponsored with technical input from SIRIM. So far about 20 such projects have been implemented.

Activities Planned

SIRIM plans to play a lead role in promotion of biogas technology in Malaysia.

148

State Bank of India,
Regional Office,
BANGALORE,
INDIA.

Contact Person: Mr. J.M. D'Souza

Phones: 53602

Gram: REMAR

Telex: 845-8195

Summary of Activities

Under National Biogas Project, 10,000 plants were targeted during 1982-83 for the Karnataka State of which State Bank of India was to finance 500 plants.

As on June 1983, SBI branches in the State have financed for 253 plants consisting of 134 KVIC model plants and 119 UAS/ Bhagyalaxmi model plants with the total loan sanctioned being 16.88 lakhs, the refinance drawn from NABARD is to the tune of Rs.7.89 lakhs.

149

State Bank of Mysore,
Head Office,
Kempe Gowda Road,
BANGALORE,
INDIA.

Contact Person: P. Raju

Phones: 28101 (6 lines)

Gram: MY BANK HEAD

Summary of Activities

Activities relate to improving the existing fixed dome designs, promotion and financing of biogas plants for rural beneficiaries, and conducting training courses for field staff in the Bank's training centres.

Activities Planned:

Currently designing a partially packed digester (fixed dome) with stirrer, safety valve, F.R.P. ceiling, prefermentation input tank etc.

150

Sukhadia University,
College of Technology & Agricultural Engineering,
UDAIPUR 313 001.
INDIA.

Contact Person: Dr. K.N. Nag,
Mr. A.N. Mathur

Phones: 3837, 3510, 3809

Gram: COLAGRENGG

Summary of Activities

Under the research project on renewable energy the parameters affecting biogas production such as the effect of climatic condition, sudden drop/rise in temperature, quantity and different types of input etc., are observed.

Two family size biogas plants using local materials and different design of input, output and digester size were constructed and observed.

Activities Planned

Research on the different models of biogas plants suited for local conditions with locally available material and manpower will be taken up for the Regional Biogas Research & Training Centre set up by the Govt. of India. Studies will also be carried out on parameters controlling gas production as well as the use of agriculture waste in biogas plants. The Institution is also engaged in construction, management and maintenance of community/institutional biogas plants.

151

Swedish Institute of Agricultural Engineering,
Box 7033,
S-750 07 Uppsala,
SWEDEN.

Contact Person: Lennart Thyselius

Phones: 018-30 19 30

Summary of Activities

Laboratory and full scale experiments on fermentation of swine and cattle manure, slaughtery waste and different plant material, comparison between fermented and unfermented manure with regard to plant nutrient value, the use of biogas for heating purposes and for conversion into electricity, etc. Preparing general safety recommendations for biogas plants also forms part of the project.

Activities Planned

Studies of the effect of ferrous salts on the fermentation process and the lethal effect on pathogenic organisms in connection with fermentation of slaughter-house waste.

152

Swiss Federal Research Station for Farm Management and Agricultural Engineering,
CH-8355 Tanikon,
SWITZERLAND.

Contact Person: Arthur Wellinger

Phones: 052/47 '20' 25

Summary of Activities

The project intends to lower the cost of biogas production by reducing process energy, increasing gas yield with biological means and optimizing gas utilization.

The first subproject seeks to optimize the mass flows, (heat, gas, manure) of biogas installations in order to reduce process energy and lower cost of gas production. a concept has been developed which allows to give farmers individual recommendations for appropriate biogas systems and gas utilizers. A full-size manure-manure heat exchanger was tested. Currently gas furnaces are checked with respect to their efficiency and material durability.

In the second item pilot plant and lab-scale studies shall bring a better understanding of accumulation systems. Special emphasis is brought to digestion at psychrophilic temperatures. Various agricultural residues in addition to the manure will be tested in view of an instant increase in gas production.

In order to optimize gas utilization, a diesel tractor was converted into a dual fuel engine and its performance is currently determined on a test stand. Prior to the tests a transportable, low cost gas cleaning and compressing unit was developed and built. The tractor shall be tested in regular field work by a research independent farmer.

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Syndicate Bank, Head Office,
Post Box No.1
MANIPAL 576 119
Dakshina Kannada District
Karnataka, INDIA.

Contact Person: Mr. K.M. Udupa

Phones: 8261

Gram: GIANT

Telex: 0842-242 & 0842-244

Summary of Activities

Introduced a scheme for financing biogas plants in 1973. The bank was the first commercial bank in India to promote biogas as a bankable proposition. So far the bank has financed construction of about 5,000 biogas plants.

The bank has been popularising biogas plants in the rural areas by organising extension education programmes on this subject. The bank has also got trained about 100 rural youths in the construction of biogas plants to enable them to take up the work of supervision of the construction of the gas plants under the supervision charges scheme of the Khadi & Village Industries Commission. This scheme enables the trained youth to earn sizeable income by popularising gas plants.

The Syndicate Agriculture Foundation promoted by the bank has been entrusted with the management of one of the few experimental community biogas plants set up in the country. The community gas plant set up at Barkur, near the Head Office of the bank has been running since January 1983 and about 25 families are benefiting from this plant.

Activities Planned

The bank has stepped up its participation in the national biogas project by undertaking to finance the biogas plants through all its rural and semi-urban branches. A special scheme covering six districts of Karnataka and Cannanore District of Kerala has been launched for intensive financing of gas plants. A competition for preparing the design for efficient and low-cost biogas plant is also being organised.

154

Taiwan,
Council for Agri. Planning & Development,
37, Nan Hai Road,
Taipei,
TAIWAN (REPUBLIC OF CHINA).

Contact Person: Dr. Chung Po

Phones: 3317541

Gram: 8515

Summary of Activities

R&D in anaerobic treatment of hog wastes in inexpensive yet long lasting RMP (Red Mud Plastic) bags has resulted in wide use of RMP biogas plants in rural areas. Recently a 20,000-head piggery has established a plant where hog wastes are first digested in ten 700 m^3 bags. The effluent receives a secondary aerobic treatment with an aerator powered by a generator with biogas as the fuel.

Activities Planned

1. Coupling of solar energy with biogas plant.
2. Up flow system.
3. Enrichment of carbon source for algae by CO_2 from biogas.

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Taiwan Livestock Research Institute,
112 Mu-Chang Road, Hsinhua,
Tainan,
TAIWAN (REPUBLIC OF CHINA),

Contact Person: Dr. J.C.C. Wang

Phone : 064-982-626

Summary of Activities

The digested sludge from plant run on hog manure was used for Spirullina cultivation.

The algae cultivation medium which is alkaline, is used to absorb the CO_2 and H_2S in biogas. Biogas thus purified has only 4% CO_2 and may be used to generate electricity.

The Institute also acts as consultant to farmers who have hog manure digesters installed on their farms.

Activities Planned

Research and development; consultation; information dissemination; etc. in the area of biogas technology.

156

Tamil Nadu Agricultural University,
Dept. of Agro Energy,
COIMBATORE 641 003.

Contact Person: Prof. K.R. Swaminathan

Phones: 35461

Gram: FARMVAR

Summary of Activities

Studies on the following aspects of Biogas Technology:

1. Microbial studies on temperature profile and micro-organism, screening of micro-organisms for large scale multiplication - feedstock substitution etc.

2. Improvements on biogas plants by use alternate construction materials, optimising the size and shape of plants, incorporating heat exchanger through solar heating device, use of double digesters, digester storage volume studies such as binory fluid storage and pressure, optimum slurry outflow due to pressure, etc.

3. Biogas scrubbing - by dissolving CO , or by chemical processing or pneumatic counterflow.

4. Detailed studies on the use of biogas in engines, improving biogas appliances.

5. Studies on the manurial value of sludge, and methods for its enrichment.

Activities Planned

1. Trainer's training, construction training and training of field functionaries and artisans.

2. Cost reduction of plants through material substitution, studies on Diphasic Digestion, optimisation of parameters and feedstock monitoring.

3. Providing technical advice and after care service of biogas plants.

4. Propagation of community biogas plants.

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Tata Research Development & Design Centre,
1, Mangaldas Road,
PUNE 411 001.
INDIA.

Contact Person: Dr. E.C. Subbarao
Dr. K.G. Gollakota

Phones: 21518

Gram: ADMINTA

Telex: 145464

Summary of Activities

The main objective has been to produce biogas from solid agricultural wastes without dependence on cow dung.

i) A mixed culture capable of degrading anaerobically a variety of cellulosic wastes to biogas in a simple mineral mixture has been isolated from cowdung and stabilised.

ii) From this a mixed culture capable of anaerobically degrading acetate to biogas in a simple mineral mixture has also been isolated and stabilised. The biogas produced from acetate contains detectable amounts of ethane providing irrefutable evidence for the microbial formation of ethane.

iii) Mixed cultures capable of anaerobically degrading non-edible oil cakes (castor or neem) to biogas have also been isolated and stabilised. The process is found to be economically viable and domestic demonstration units have been functioning satisfactorily.

iv) Process for biogas production from mixed feeds (oilcake and cellulosic waste) has also been developed and domestic units based on this process have been functioning satisfactorily.

v) Mixed cultures capable of degrading propionate, butyrate and stearate in simple chemically defined media have also been isolated and stabilised.

Activities Planned

a) Develop processes for utilization of other non-edible oil cakes and cellulosic wastes used singly or in combination.

b) Extend the studies on the microbial production of the lower aliphatic hydrocarbons other than methane.

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Bangkhen, Bangkok 10900,
THAILAND.

Contact Person: Mr. Chaiyuth Klinsukont
Mr. Preecha Ploypatarapinyo

Phones: 5791121-30

Gram: TISTR

Summary of Activities

During the 4 years, 3 projects relating to biogas technology were accomplished.

1. Production of Biogas from Animal Wastes Using Anaerobic Packed Digester.

2. Evaluation of Treatment Alternatives for Molasses Distillery Stillage: Treatability of the stillage on anaerobic contact and anaerobic filter designs is carried out continuously with special emphasis on methane gas production.

3. Treatment of Slaughter House Waste-water for Energy Reuse by Anaerobic Contact and Anaerobic Filter Designs: The objective was to determine basic engineering design data for slaughter house waste-water treatment.

Activities Planned

Treatment Alternative for Cassava Distillery Stillage by Anaerobic Contact and Anaerobic Filter as part of a joint project between TISTR and the JAIF (Japanese Association of Industrial Fermentation) on "Pilot Scale Alcohol Production Process".

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Thapar Polytechnic,
Patiala,
INDIA.

Contact Person: D.R. Gupta

Summary of Activities

Thapar Polytechnic has so far installed 66 Janata Model Gobar Gas Plant in 48 villages. The Community Polytechnic Wing has conducted 5 training camps for Master masons/supervisors and trained 47 masons on construction of Janata Biogas Plants. It has been conducting regular 1 day workshops for biogas users on efficient operation, maintenance and care of the plant. In its promotional efforts, it has published and disseminated literature like biogas plant drawings, demontional details, detailed instructions of its construction, operation and maintenance and treatise on Janata Model Biogas Plants, etc. It has actively collaborated with state nodal agencies for providing technical support and training.

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United Nations Economic & Social Commission for Asia & Pacific,
Natural Resources Division,
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Rajadamnern Avenue, Bangkok 10200,
THAILAND.

Contact Person: Dr. Van-Vi Tran

Phones: 282-9161

Gram: ESCAP BANGKOK

Telex: 82392 ESCAP TH

Summary of Activities

- Publishing the guidebook on biogas development.

- Two training courses on biogas in China under the REDP activities organized with FAO.

- Held a workshop on uniformity of information reporting on biomethánation systems.

Activities Planned

1. Updating the guidebook of biogas development.

2. Organising workshop on biogas technology.

3. Providing technical advisory services to the ESCAP member countries.

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UNEP/UNESCO/ICRO Microbiological
Resources Center
Karolinska Institute
S 104 01 Stockholm
Sweden

Contact Person : Prof. Carl-Goran Heden
Mr. Eng-Leong Foo

Gram : 08/33 54 11

Telex : 08/34 05 60 ext 1627

Summary of Activities :

A Project on COMPUTER CONFERENCING IN ANAEROBIC DIGESTION (1984 - to date). has been set up (a) to link individuals, organizations and biogas networks, by mail or via computer conferencing system networks, for information exchange, technical discussions and to encourage coordination and collaboration in anaerobic digestion: (b) to organize computer conferences for electronic discussion of papers/posters presented at face-to-face meetings; (c) to organize working groups for specific task (d) to establish a data base for anaerobic digestion for organization profiles, bibliography and resources.

Current members (Oct 84) of teleconference are from USA, Canada, Spain, FRG, DDR, Denmark, Finland, Russia, Yugoslavia, Greece, India.

Publications include Proceedings of teleconferences ANAEROBIC DIGESTION MIRCEN.

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Universidad Autonoma De Santo Domingo,
Cindad Universitaria,
Santo Domingo,
REPUBLICA DOMINICANA

Contact Person: Prof. Pedro Gomez Perez

Phones: 533-1560

Summary of Activities

As part of the Energy Programme, a project for determining the optimal parameters in the production of biogas from vinase (alcohol distillery slops) have been completed besides installing and operating a plant on a 500 heads cow farm. Another project included the study of biogas use as fuel in small gasoline engines (1-3 Hp) to move electric generator and determining the biogas consumption at different carburator modifications and power demand. The installation, operation and utilisation of a 50 m3 Chinese type biogas plant using food leftovers (rice, beans, etc.) is in progress.

Activities Planned

1. Pilot-scale biogas plant for vinase treatment (in distillery) to lower its BOD.

2. Parameters determination of using agricultural leftovers in biogas production (coffee pulp, and others).

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Universidad de La Laguna,
Departamento de Quimica Tecnica,
La Laguna - Tenerife,
SPAIN.

Contact Person: Dr. Francisco Jarabo

Phones: 34-22-258230 ext. 267

Summary of Activities

Conducts laboratory scale studies on the batch and daily fed anaerobic digestion of sewage sludge and agricultural wastes like banana stems. Parameters like substrate concentration, retention time and others are examined to develop some kinetic models.

The Department also conducts Graduate courses on Renewable Energies and Energy from Biomass. Also several articles on renewable energy sources have been brought out.

Activities Planned

Apart from continuing the present activities there are plans to take up research on anaerobic digestion of chicken manure work.

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Universidada Estadual De Campinas (UNICAMP),
Faculdade De Engenharia De Campinas,
Cidade Universitaria,
Campinas - SP,
BRAZIL.

Contact Person: Antonio Augusto Pires De Oliveira Filho Sergio Salazar

Phones: (0192) 391301

Summary of Activities

Operaton of a research model (2 m capacity) of biogas plant using water hyacinth as input. Research on the anaerobic digestion of the water hyacinth juice at the laboratory stage using upflow digesters (capacity 10 litres.)

Activities Planned

Design of a sequence of tests for water hyacinth juice using upflow digesters (capacity 100 litres); study of the use of bagasse as fertiliser.

Construction of a pilot plant with processing capacity of 10 tons/day of water hyacinth located at the reservior of the Americana Hydroelectric Plant.

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Universidada Federal Da Paraiba,
Laboratorio de Energia Biomassa,
Centro de ciencias Agrarias,
Areia - Pb. 58397.
BRAZIL.

Contact Person: Kuzhiparambil Prakasan

Phones: (083) 362 2300 R-122

Summary of Activities

Three biogas plants are in operation - Indian horizontal vertical models and a Chinese model plant. Two more plants, one of Indian model and the other of Chinese model are being constructed to supply biogas for the University Restaurant. Utilization of sludge for animal feed, fish culture and mushroom culture, utilization of soil cement for the plant construction are few of the present research activities of the laboratory.

Activities Planned

1. Construction of demonstration plant units in the ruaral areas.

2. Study the possibility of utilisation of soil cement as construction materials for biogas plants.

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Universitat Autonoma de Barcelona,
Department de Quimica Tecnica,
Bellaterra (Barcelona),
SPAIN.

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Telex: 52040 EDUCI E

Summary of Activities

The laboratory reserach work on anaerobic digestion of wastes includes:

- Batch kinetics of glucose and volatile fatty acids degradation using an enriched culture.
- Degradeability of landfill leachate and biogas production using a completely mixed digester.
- Accimilation and inocula selection in the mesophilic and thermophilic anaerobic digestion of industrial wastewaters.
- Maximization of biogas production and organic matter removal in the anaerobic treatment of agricultural and animal wastes.
- Anaerobic process development (packed, fluidized and expanded bed systems).

Pilit plant studies are being carried out using a 2 m^3 anaerobic filter treating the liquid fraction of the piggery wastes, while the full experience includes the control of a 100 m^3 digester.

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University College,
Dept. of Microbiology,
Galway,
IRELAND.

Contact Person: Dr. Emer Colleran
Dr. Aun Wilkie

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Summary of Activities

Since 1980, Anaerobic Digestion studies at University College, Galway have been concerned with the development of the anaerobic filter design and with its application to biogas production from agricultural wastes.

Since digestion of raw pig slurry by an anaerobic filter would result in clogging of the matrix bed by the particulate material in the slurry feed, a two-stage approach, incorporating an initial solids liquefaction step, was adopted.

Studies on anaerobic filter digestion of silage effluent at a variety of feed strengths and retention times conducted. A two-stage system was developed at laboratory scale for crop residue digestion.

Activities Planned

A detailed study on the effect of varying the nature and packing arrangement of the support matrix and of feed flow direction on anaerobic filter performance is currently in hand. Detailed digestibility trials on the various waste streams from milk processing plants have been initiated. Studies on the performance of anaerobic filters under thermophilic conditions and the factors governing microbial attachment to support material surfaces will also be investigated.

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University of Arkansas,
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U.S.A.

Contact Person: E.C. Clausen
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Summary of Activities

Research work during the past two years has concentrated on decreasing the size of digestors in continuous-fed plants. Since the overall reaction kinetics are quite slow, the digestor is quite large, often exceeding 65% of the total capital investment. Specific research projects include high solids feed concentration studies, cell recycle studies, and culture enhancement studies. These techniques may be employed by themselves or in combination. A significant decrease in capital costs is possible by using these techniques. This work has been sponsored by the Solar Energy Research Institute and Argonne National Laboratory.

Earlier efforts were on the lines of using agricultural residues like corn stover for biogas production. Research efforts were divided into two phases: the development of small scale farm system using batch fed plants and the development of large scale industrial facilities to utilize continuous flow plants.

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University of British Columbia,
Dept. of Bio-Resource Engg.,
2075 Wesbrook Mall,
Vancouver, B.C. V6T 1W5,
CANADA.

Contact Person: K.V. Lo

Summary of Activities

1. Feasibility of increasing biogas production using advanced biogas plant concepts with liquid-solids separation treatment. This involves selecting proper screen size for liquid-solid separation pre-treatment based on optimum volatile solid levels, comparison of various laboratory-scale and conventional plants, evaluation of the most promising plant design on a pilot scale and evolving design criteria for assessment of the farm scale plants.

2. Developing design criteria for construction of on-farm scrubbers for removal of carbon dioxide and hydrogen sulphide from biogas and to field test the scrubbers with pilot-scale plants for modification.

3. Developing a pH and methane concentration sensor for continuous monitoring of on-farm biogas plants and their field testing with pilot-scale plants.

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University of London,
Queen Elizabeth College,
Microbiology Dept.,
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London W8 7 AH,
ENGLAND.

Contact Person: Prof. S.J. Pirt

Phones: 01 937 5411

Summary of Activities

Microbial conversion of glucose to methane: conditions required to maximize the yield and rate of conversion.

A methanogenic co-culture was derived from anaerobic digestion. Two bacterial species have been isolated from this co-culture and named Anaeroplasma (strain London) and Methanoplasma elizabethii. The function of the former is to convert glucose to ethanol, acetate, H_2 and CO_2 while the latter generates CH_4 from CO_2 and H_2.

Activities Planned

1) To characterise further the Methanoplasma.

2) To determine the roles of the facultative anaerobes in the co-culture.

3) To increase the yield of methane.

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Dept. of Management Studies,
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INDIA.

Contact Person: Prof. R.V.R. Sivagnanam

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Gram: UNIVERSITY MADRAS

Summary of Activities

Planning and Development of Biogas Systems in Tamil Nadu - a Management Perspective: A Project set up with a view to:

1) Evaluate the potential of biogas as a source of energy, bio-fertilizer for food production and means of pollution control.

2) Review the progress of biogas plants in Tamil Nadu with reference to the above uses.

3) Assess the awareness and attitudes of the present and prospective biogas plant users regarding financial subsidies and technical facilities for plant-installation, servicing and maintenance.

4) Assess the effectiveness of organisational network for implementing biogas schemes in Tamil Nadu.

5) Draw up a techno-economic feasibility study for setting up biogas plants for energy conservation and pollution control in urban/semi-urban locals by municipal organisations.

Activities Planned

In addition to those summarised under (5) above, it is proposed to study rural energy consumption patterns in Tamil Nadu and to collect and disseminate information on biogas systems.

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University of Melbourne,
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AUSTRALIA.

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Gram: UNIMELB

Telex: AA 35185

Summary of Activities

Laboratory procedure for measuring the biogas production from different substrates. Most measurements have been made on pig manure from different sources and incubated at mosophilic or thermophilic temperatures.

Activities Planned

Measurements will continue on a range of substrates.

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University of the Philippines, Los Banos College,
National Institute of Biotechnology and Applied Microbiology (BIOTECH),
Laguna,
PHILIPPINES.

Contact Person: Dr. William G. Padolina

Phones: 2359

Summary of Activities

For the period, experiments on biogas production are focused on the search for indigenous materials with basic properties that can be used to preheat rice straw in order to enhance its digestibility as substrate for biogas production. Coir dustash, rice straw ash, bagasse ash leachate,lime and soda ash are being tried as pretreatment materials for rice straw.

Activities Planned

a. Evaluation of the different plant designs and prototypes according to size, efficiency and cost; and

b. Feasibility study of integrated renewable energy farm systems with biogas plant as the integrating unit.

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426 chemindes Patriotes,
St., Charles sur Richelieu,
Quebec, B.P. 60,
JOH 2GO,
CANADA.

Contact Person: M. Cournoyer

Summary of Activities

1. Evaluate certain parameters which can be used to identify and control the health of the digester.
2. Evaluate the actual production of the digester, the quality of the biogas and the stability of operation at 30°C.
3. To examine the use of biogas for electricity generation.
4. To evaluate the effectiveness of the system for heat recovery.
5. To evaluate a synthetic material for methane storage.
6. To evaluate equipment for stripping water and hydrogen sulfide from the biomass.
7. To study the constraints imposed by the digester on the operations of the farm.
8. To evaluate the systems profitability.

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The Vidyavanam Public Trust,
PAMARU 521 157.
Krishna District, A.P.
INDIA.

Contact Person: Mr. Y.S. Mohan Rao

Phones: 240 & 310 (Pamaru)

Summary of Activities

Installed 3,000 family size and three community biogas plants in Andhra Pradesh. Developed ferrocement biogas holders and digesters in collaboration with Khadi & V.I. Commission.

Activities Planned

Planning to instal 4,000 family size and ten community biogas plants. A commercially viable design for digesting other agricultural wastes is intended to be developed. Planning to work on use of sludge in fish farming and agriculture.

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Warren Spring Laboratory,
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Gunnels Wood Road,
Stevenage,
Herts SG1 2 BX,
ENGLAND.

Contact Person: Mr. N.W. Le Roux

Phones: 0438 313388

Telex: 82250

Summary of Activities

Continuing interest in the anaerobic digestion of putrescible fractions obtained from sorted household waste and possible co-digestion with sewage sludge to produce biogas.

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Waterloo University,
Dept. of Chemical Engg.,
Waterloo,
Ontario N2L 3 G1,
CANADA.

Contact Person: M. Moo-Young

Summary of Activities

A free-standing anaerobic fermentation process to generate fuel gas as the main product is planned. The solids conversion efficiency (liters gas produced/g solids added) and the concomitant gas generation rate for a range of agricultural and forestry wastes (separately and in combinations) which are widely available in Canada are to be determined. Detailed economic analysis of a number of scenarios pertinent to the types of raw materials available in representative regions of Canada will also be undertaken.

CHAPTER - 18

BIOGAS TECHNOLOGY FACT SHEET

1. Productivities of Crop Residues

Crop Residue	Residue yield (tonnes/ha)
1. Rice husk	1 to 1.3
2. Wheat straw stubble	3 to 3.5
3. Leaves and stalks from corn	6 to 10
4. Leaves and stalk from sorghum	6 to 7
5. Bagasse	20 to 25
6. Pulp from sugar beet	8 to 15
7. Groundnut shells (and biomass)	0.60
8. Coconut shells and wastes	0.4
9. Forest wastes	1.2
10. Arecanut shells and fronds	2.0
11. Sunflower stalks	2.5

2. Productivities of Aquatic Plants for Energy Generation

Plant type	Yield (mean) dry ashfree) tonnes/ha/year	
	Mean	Range
1. Water hyacinth	60	50 to 60
2. Algae	40	30 to 50
3. Marine Macrophytes	29	20 to 40
4. Mscophylum	24	20 to 26
5. Laminaria	40	30 to 48

3. Estimates of Human and Animal Wastes Available in Indian Conditions

Sl. No.	Source	Total waste Kg/day/head	Collectable waste Kg/day/head
1.	Cattle	10 to 15	5 to 8
2.	Pigs	1.3	0.30
3.	Sheep	0.75	0.25
4.	Man	0.75	0.75
5.	Kitchen wastes	0.25	0.25
6.	Poultry	0.06	0.06

4. Estimated Potential of Biogas Technology in Asian Countries

Country/Region	Potential
China	- 1,400 billion tonnes of animal and human excreta are available. One kg, when fermented, produces 3350 kJ.
India.	- 18,750,000 family-size biogas plants (1.7 m^3 of gas/d) and 560,000 community plants (142 m^3/d).
	- 2,350 million Cft (66.5 million m^3) biogas per day, equivalent to 4.12 million tons of coal a year of 1095 million gal (243 million liters) of petrol a year.
Korea, Republic of	- 311,981 m^3 of biogas produced in 1977 from cow, pig and chicken wastes. Equivalent to 1,095,400 barrels of kerosene, or 2,063 Megawatt-h.
South-East Asia	- Biogas from 60% of animal wastes produced in 1975 equivalent to 8.9 x 10^9 liters of petroleum.
Pakistan	- 2,327 million m^3 of biogas produced from 50% of cattle dung, equivalent to 9.183 million barrels (1.25 million tons) of oil.
Indonesia	- 15.975 million m^3 of gas per day.
Malaysia	- 1.962 million m^3 of gas per day.
Philipines	- 10.083 million m^3 of gas per day.
Singapore	- 0.680 million m^3 of gas per day.
Thailand	- 17.017 million m^3 of gas per day.
Nepal	- Theoretical potential of 790 m^3 of gas, and economic potential of 316 million m^3 of gas. Equivalent to 3.21 million and 1.28 million, respectively, tonnes of coal.
	- Theoretical potential of fresh dung : 28 million tonnes per annum.

5. System Efficiencies of Biomass based Secondary Fuel Production *

Sl. No.	Process	Secondary fuel	(Efficiency %)
1.	Briquetting	Wood briquettes	85
2.	Pelletisation	Wood pellets	80
3.	Direct combustion	i) Process steam ii) Electricity	25 to 45 10 to 15
4.	Gasification with air	i) Low energy gas ii) Heavy oil	70 to 80 35
5.	Pyrolysis	Pyrolytic oil, char and low energy gas	45 to 65
6.	Carbonisation	Charcoal	20 to 38
7.	Liquifaction	Heavy oil	40 to 50
8.	Ethanol fermentation	Ethanol	30
9.	Destructive distillation	Methanol	35
10.	Anaerobic digestion at ambient temperature	Biogas	30
11.	Anaerobic digestion at 40°C	Biogas	60 to 75

* **Note :-** Efficiencies include external energy inputs like electricity.

6. Raw Materials Characteristics : Animal Waste

Type of waste	C/N ratio	% of H_2O	kg VS animal unit / day	gm/l	1 / day
Cowdung	16-25	78-80	4.2	1020	37.3
Horse manure	25	75	-	-	-
Pig waste	14	82	2.7	945	28.3
Poultry litter	9.3	65	5.9	960	28.3
Sheep manure	20	68	-	-	

7. Rate of Biogas Production from Animal Wastes

Type of waste	kg VS produced/ animal unit/day	% VS destru-ction	Normal max. cc biogas/gm VS destroyed	m^3 biogas/ animal unit/ day	Calx10^3 methane/ animal unit/day
Cow	4.0 kg	30%	800 cc/gm	1 m^3	5.2 Calx10^3
Pig	2.7 kg	50%	1100 cc/gm	1.6 m^3	8.2 Calx10^3
Poultry	5.9 kg	60%	600 cc/gm	2.2 m^3	11.3 Calx10^3

8. Basic Information on Animal Requirement for Biogas Production *

Particulars	Pigs	Cows and Buffaloes	Chicken
Amount of manure per 500 kg. animals (kg/day)	28.4	38.5	31.3
Amount of manure per 500 kg. animals (litres/day)	28	38	28
Required weight of animals (kg.)	243	334	158
Gas volume (m^3/kg of manure)	0.0872	0.0467	0/1215
Weight of manure for producing gas 1.2 m^3/day, kg	13.8	25.7	9.88
Average weight of animals, (kg/head)	60	180	1.5
Amount of animals required	4	2	105

* **Note :-** Calculated from data published in National Academy of Sciences' Report and ESCAP Biogas Newsletter

Source : Biogas production from farming wastes. Tumlos, E. AIT, Bangkok. 1981 p.3

9. Raw Materials Characteristics : Plant Wastes

Raw Materials	%C	% N	% M	C/N
1. Water hyacinth	44.24	2.16	19.27	20.51
2. Sorghum	50.95	0.50	7.80	100.85
3. Leaves	47.84	1.48	4.66	32.25
4. Mixed grass	49.83	1.34	9.73	37.13
5. Rice straw	48.25	1.34	6.78	78.58

Source : Biogas Production from Farming Wastes. Tumlos, E.T. AIT, Bangkok, 1981. p.14.

10. Biogas Production from Various Types of Crop Residues (litre per kg dry matter)

Type	Retention Time (days)	Dry matter (%)	Total Dry Matter (kg)	Gas Production (1/kg dry matter)
Rice straw	33	46	4.6	5.67
Ipil-Ipil	46	28	2.8	7.51
Paragrass	36	30	3.0	5.05
Sugarcane top	43	20	2.0	7.31
Cucumber leave	40	24	2.4	5.18
Duck weed	41	22	2.2	5.46
Corn top	32	19	1.9	5.43
Water hyacinth	46	12	1.2	20.3

Source : Biomass energy through microbial processes by M. Tanticharoen. In US-ASEAN Seminar on Energy Technology : Biomass, Coal, Solar, Wind Energy Planning, Indonesia, June 7-18, 1982. p.111.

11. Composition of Biogas Produced from Different Types of Crop Residues

Crop Residues	Gas composition (% v/v)					
	CH_4	CO_2	O_2	H_2	N_2	H_2S
Rice straw	22.8	24.8	1.2	0.4	50.8	-
Ipil-ipil	24.9	19.4	6.4	0.7	48.6	-
Paragrass	4.3	23.2	2.6	0.6	69.3	-
Sugarcane top	9.6	22.4	2.0	0.4	65.6	-
Cucumber leaves	-	14.8	1.7	1.3	82.2	-
Duck weed	11.3	32.2	1.6	0.2	54.7	-
Corn top	7.6	28.0	0.8	0.2	63.4	-
Water hyacinth	8.2	16.6	2.1	0.5	72.6	-

Source :- Biomass Energy through Microbial Processes by M. Tanticharoen. Ibid. p.111.

12. Selection of Appropriate Size of Plant

No. of family members for kitchen fuel (ft^3)	Approx. No. of Cattles	Daily requirement of wet dung (kg)	Size of biogas plant per day m^3 (ft^3)
5 - 8	3-4	30-45	2 (70)
8 - 12	4-5	40-50	3 (105)
12 - 16	5-7	55-60	4 (140)
16 - 20	7-10	80-100	6 (210)

Source : - Development of Biogas Technology in India. O.P. Singhal. Steam & Fuel Users J. 33; 3-4; 1983-84; p.53.

13. Calorific Value of Biogas and Other Major Fuels

Fuel	Unit	Calorific value	
		(MJ)	(kcal)
Biogas	m^3	20	(4,700)
Electricity	kWh	3.6	(860)
Kerosene	litre	38	(9,100)
Charcoal	kg	29	(6,900)
Firewood	kg	20	(4,700)
Butane	kg	46	(10,900)
Cattle-dung cakes	kg	8.8	(2,100)

14. Biogas Requirements for Typical Applications *

Purposes	Specifications	Gas Required, m^3	Country
Cooking	Per person	0.5/day	China
	Per person	0.34-0.43/day	India
	Per person	0.425/day	Nepal
Gas Stove	5 cm dia.	0.33	
Gas Stove	10cm dia	0.47	
Boiling Water	15cm dia.	0.64	
Boiling Water	Per gallon	0.28	
Lighting	200-candle power	0.1	China
	40-watt bulb	0.13	India
	1-mantle	0.07-0.08	
	2-mantle	0.14	
	3-mantle	0.17	
Gasoline engine	Per hp	0.45	India (Engine efficiency 25%).
	Per hp	0.41	Pakistan (Engine efficiency 28%)
	Per hp	0.43	Philippines
Diesel engine	Per hp	0.45	Pakistan (Compression ratio 20)
Generating Electricity	Per kwh.	0.616	
Refrigerator	Per m^3	1.2	U.K
Incubator	Per m^3	0.5-0.7	Nepal
Table fan	30 cm dia.	0.17	
Space heater	30 cm dia.	0.16	

* **Note :-** Data are expressed per hour except as indicated.

15. Gas Consumption for Different Types of Burners

S. No.	Usage of Gas	Gas Consumption (flow rate)
1.	One standard burner (large)	16 cft./hr
2.	One large, one small burners or one large burner and two lamps	24 cft./hr
3.	Two large burners or one large and one small burners and two lamps	32 cft./hr
4.	Three large burners	48 cft./hr
5.	Four large burners	64 cft./hr

Source :- Designing Biogas Distribution System. Anil Dhussa. Bio Energy Renews, 2; 1-2, 1983; p.70

16. **Pressure and Temperature Required to Liquify Biogas**

Pressure $(Kg/cm)^2$	Temperature (°C)	Volume of cylinder (m^3)
80	-70	0.10
100	-50	0.14
130	-25	0.14
160	0	0.15
160	25	0.20

Source :- Development of Biogas Technology in India. O.P. Singhal. Ibid. p.54.

17. Recommended Pipe Diameters for Varying Flow Rates and Distance Between Biogas Plant and Points of Use

Distances/ Flow Rate	25 m	50 m	100 m	150 m	200 m	300 m	400 m	500 m
16 cft/hr	1/2"	3/4" for 25m 1/2" for 25m	3/4"	3/4"	1" for 150 m 3/4" for 50m	1" for 200 m 3/4" for 100 m	1" for 350 m 3/4" for 50 m	1"
24 cft/hr	1/2"	3/4"	3/4"	1" for 100m 3/4" 50 m	1" 150 m 3/4" 50 m	1"	1.1/2" 200 1" 150 3/4" 50	1.1/2" 200 1" 300
32 cft/hr	3/4"	4/4"	3/4"	1" 100 3/4" 50	1"	1.1/2" 200 1" 50 3/4" 50	1.1/2" 200 1" 200	1.1/2" 350 1" 150
48 cft/hr	3/4"	3/4"	1" 75 mm 3/4" 25m	1"1	1"	1.1/2" 150 1" 150	1.1/2" 300 1" 100	1.1/2" 400 1" 100
64 cft/hr	3/4"	1"	1.1/2" 50 m 1" 50 m	1.1/2" 100 1" 50 m	1.1/2" 150 1" 50	1.1/2"	1.1/2"	2" 150 1.1/2" 350

Source : Designing Biogas Distribution System by Anil K. Dhussa. Bioenergy Renews, 2, 1&2; 1983; p.71

18. Nitrogen Content in Typical Biomass Wastes

Waste	% Nitrogen on Dry Basis					
	Burma	China	Fiji	India	Malaysia	Vietnam
Human				5-7		7.0
Buffalo	1.4	0.3				1.7
Cow	1.4		1.8	1.4-1.8		1.3
Horse	5.5					
Pig	4.0	2.1	1.9		1.9	2.2
Goat	2.7		2.0			
Sheep		0.7				
Chicken	2.7	1.6	4.2		4.0	1.9
Duck	1.6					5.5

19. Nitrogen Transformations in a Digester

Input Material	Influent		Effluent		Unit Expression
	Total N	NH_3	Total N	NH_3	
Night soil	1.049	0.62	1.009 (-3.8)	0.86 (+38.7)	
Pig manure	109	59.2	106 (-2.7)	79.4 (+34.1)	g/d
Pig manure: hay = 4:1	17.55	-	15.8 (10.0)	-	g/jar
Pig manure:cattle manure : hay = 1:1:1	23.71	-	22.68 (-4.3)	-	g/jar
Pig manure : cattle manure : feces = 3:1:1	37.23		36.23	-	g/jar

20 **Nutrient Content of the Sludge** *

Experiments	Organic Matter (%)	Total Content (%)			Available in slurry form (%)	
		N	P_2O_5	K_2O	N	P_2O_5
Group I	30.6	0.974	0.926	2.00	0.080	0.486
Group II	61.0	1.863	1.093	1.04	0.228	0.695
Group III	47.7	1.496	0.867	1.15	0.153	0.502

***Note :** i) Calculated by dry weight. Samples were dried at 60°C.

ii) The input materials used are pig manure, hay and night-soil.

21. **Biogas Financing in India and China**

Source of Finance	India	China
Central Government Subsidy	33.3% (of initial cost)	30-40% (of initial cost)
Funds from Team/ Brigade/Commune/ loans from banks	No. formal provision for bank loan Subsidy is distributed through banks	20-50%
Beneficiaries' Contribution	66.7%	20-50%

GLOSSARY

Acid-Phase Digestion :

The first stage of anaerobic digestion in which complex molecules are broken down to simpler molecules like fatty acids, alcohols, CO_2, etc. This chain of reactions is brought about by certain strains of hydrolytic and acetogenic bacteria.

Anaerobic fermentation :

A complex microbiological reaction by which complex organic materials are broken down into methane, CO_2, nitrogen, H_2S and several other gases. The process involves several strains of facultative and obligate bacteria and is accomplished in two stages - the acid forming stage and the methane-forming stage.

Batch Feeding :

In a batch digestion process, material to be digested is loaded (perhaps with a seed) into the digester at the start of the process. The digester is then sealed and the contents left to ferment. At completion digested sludge may be removed and the tank reloaded. Daily gas production varies during the process; it is slow at the srart, passes through a maximum and declines towards the end of the digestion cycle.

Biogas :

A combustible mixture of gases produced by the anaerobic fermentation of organic materials. The mixture is composed chiefly of methane and carbon dioxide.

Biogas Plant :

The physical installation where the anaerobic fermentation takes place. It consists mainly of a digester and a gasholder.

Carbon Nitrogen Ratio (C/N) :

Is the ratio by weight of carbon to nitrogen in a sample. In general a ratio of around 20-30:1 is considered 'best' for anaerobic digestion.

Continuous Feeding :

It involves the continuous feeding of waste material with the removal of the equivalent volume of treated waste (digested sludge). The process is usually started with the addition of a seed; it may take several detention days before the process conditions become steady. For many purposes this is more efficient and convenient than batch digestion. Process involving daily addition and removal are mostly properly described as semi-continuous.

Digester :

An airtight rectangular or spherical tank where the fermentation takes place. The slurry is fed to the digester through an inlet pipe.

Dilution Rate :

It is the reciprocal of the mean retention-time of the flowing medium in the digester. Thus, D=1/R.T.

Diphasic Digestion :

A two-stage fermentation process in which the acid-forming and methane forming stages are separated. A diphasic plant consists of a larger, batch fed, cold, acid-forming phase and a smaller continuous fed methane-forming heated phase.

Dry Fermentation :

This is the fermentation of relatively

dry mixtures of organic materials.

The minimum moisture level required for dry fermentation has been found to be as low as 68% of the total weight.

Dual Fuel Engine :

An engine which is designed to operate on both petroleum fuel (diesel/petrol) and biogas where both are injected into the cylinder in the ratio of 20% petroleum to 80% biogas for firing.

Effluent :

The liquid portion of the slurry which floats above the sludge.

Gas Holder :

This is an inverted drum on a dome-shaped structure for collecting the biogas generated in the digester. The gas holder may or may not be an integral part of the digester.

Gas Production :

It is the quantity of gas (whether total) biogas or methane as indicated, generated per unit of time, and normally expressed as ft^3/day or m^3/d. This should always be quoted under standard conditions of temperature and pressure.

Hydraulic Retention Time :

The number of days an average unit volume of slurry stays in the generator, i.e. from the day slurry is charged till it comes out of the digester.

Methane :

It is a compound of carbon and hydrogen; it is a colourless odourless, inflammable gas, the main constituent of natural gas and biogas.

Methane-Phase Digestion :

This is the second stage of anaerobic fermentation. In this stage, certain methanogenic bacteria convert the fatty acids and alcohols to methane, carbon dioxide, hydrogen sulphide and other gases.

Organic Loading Rate :

The total weight of volatile solids fed into the plant each day divided by the volume of the digester. Typical units are mg VS/M^3 day.

Scrubbing :

It is the process of upgrading the gaseous mixture of biogas by stripping off CO_2 H_2S and other gases by physical and/or chemical methods.

Scum :

The floating and often imperneable mass of material formed on top of the standing slurry. The problem of scum formation is severe digesters receiving much fatty or floatable material.

Sludge :

It is residue remaining after digestion, containing some undigested solids, and stabilised organic matter; it is a black tarry-smelling sludge with value to soils, both for its content of nutrients and stabilised organic matter.

Slurry :

The mixture of feedstock and water (generally in the ratio of 1:1) which is fed into the plant for biogas generation.

Thermophilic Digestion :

This refers to anaerobic fermentation during temperature of 55°-70°C. Certain species of anaerobes capable of surviving within this range have been identified. Thermophilic fermentation is assumed to enhance the rate of fermentation.

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APPENDICES

APPENDIX I

FEEDSTOCK MIX BASED ON C/N RATIO

The C/N balance line is intended to visualise the problem of balancing two different C/Ns to get the target C/N for the mixture. Assuming that the C/N of substrate A is 48 and that of substrate B is 6, the target/optimum C/N is 30. Hence the C/N balance point is 30. The distance between the balance point and the two C/Ns are different. The C/N line will be balanced when the weight times the distance of substrate A equals the weight times distance of substrate B. So if a unit weight of substrate B is hung on the one side.

(Weight of A) distance 18 (i.e. 48-30) = (Weight of B=1) (distance 24 (i.e. 30-6))

$$(A)\ (18) = (1)\ (24)$$

$$18 \times A = 1 \times 24$$

$$A = 24 \div 18 = 1.33$$

For every unit of weight of substrate B 1.33 unit weights of substrate A are required to get the target C/N.

APPENDIX II

PLANT SIZE SELECTION

Digester Size

Assumptions :

i) 36 litres of biogas is produced by 1 kg of cattle dung in 50 days.

(ii) The slurry temperature is 27°C.

(iii) 1 litre of water is mixed with each kg of cattle dung.

(iv) Approximately 14 kg of dung is produced per cattle-head per day.

(v) 1 kg of dung = 1 litre volume.

If 1 m^3 of biogas is required per day

$$\frac{1000}{36} = 28 \text{ kg of dung = i.e. about 2 head of cattle}$$

The volume of digester to produce 1 m^3 of gas per day

$$= (28 + 28) \times 50 = 2.8\ m^3$$

The same methodology can be used to calculate the digester size in situations where other types of input materials are used.

Gasholder Size

The gasholder size varies with the type of use intended to be made for biogas. For instance, if all the gas is used to run an engine for 3 hours a day, the gasholder must be able to store $\frac{21}{24}$ i.e. 88% of the gas produced.

On the other hand, if it is used to run a refrigerator then a very small gas storage capacity is needed. On an average, the gasholder must be able to store about 60% of the gas produced.

OPTIMISATION OF PLANT DIMENSION

Assumptions

Plant model selected - KVIC model with floating drum steel gasholder

y (maximum fraction of daily gas production
= 0.6 (60% of the rated daily gas production)

C (maximum plant capacity)
= 200 cu ft/day

Diameter of the digester will be slightly more than that of the gasholder; but for convenience, both the diameter of the digester and gasholder are assumed to be the same.

t_d = Detention time = 52 days.

$P_s l$ = density of slurry = 1 g/cm^3

Y = gas yield per unit weight of dung = 3.4 cm^3/g wet dung

B = thickness multiplied by unit cost of masonry in Rs/unit = 6.75

a = tpu = 22

Calculation of Size

Diameter of the digester can be calculated as follows :

$$D_K = 8_y/\pi)^{1/3} \quad C^{1/3} = 6.736 \text{ ft}$$

Height of the gasholder is

$$h_K = 4\, yC/\pi\, D_K^2 = 3.4 \text{ ft}$$

Height of the digester

$$h'_k = 8\, \phi\, C/\pi\, D_K^2$$

$$h'_k = 8 \times 1.5294 \times 200/\pi \times (6.736)^2 = 17.18$$

Height to depth ratio of the digester

$$h'_k/D'_k = 17.18/6.736 \approx 2.6$$

This implies that narrow and deep digesters are suited.

Optimisation To Reduce Cost

The diameter of the digester and that of the gasholder corresponding to the minimum total capital cost is given by

$$D'A = D_A = 8\, \delta/\ \pi\, \epsilon\ )^{1/3} \quad C^{1/3}$$

where

$$\beta = t'u$$

$$\delta = ay + 2\phi\beta \quad (1 + \frac{1}{\pi})$$

$$\epsilon = a + \beta$$

$$D'_A = D_A = (8 \times 40.422318/- (8 \times 40.422318/\pi\, 28.75)^{1/3} (200)^{1/3} = 8.925$$

The height to depth ratio for a digester pit optimised is

$$h'_A/D'_A = h'_A/D_A = \phi\, \epsilon/\delta$$

$$= 1.5294 \times 28.75/40.422318$$

$$= 43.970250/40.422318$$

$$\approx 1.1$$

This implies that the optimised dimensions correspond to wide and shallow digesters with depths almost equal to the diameters, when the total capital cost of gasholder and digester is minimised.

The gasholder height is determined by the gas stored, that is required

$$h_A = h_y\, c/\pi\, D^2A = 1.9$$

RECENT PUBLICATIONS : 1985

A. Bibliographies

1. *Indian Energy Index :* Non-Conventional Energy Literature 1950 - 1982. Compiled by Arup Roy Chaudhury and V. Vijayalekshmy. May 1985. 265p. Out of stock.

   Based on extensive literature searches and several bibliographies published earlier, the present publication supercedes Indian Solar Energy Resource Index 1975 - 80 of May 1980. The Index covers over 2,600 titles on topics such as solar energy, biotechnology and bioenergy, wind, geothermal, hydrogen energy as well as energy management and conservation, rural energy systems, etc, A personal author index and a list of about 120 major resource journals are the other features.

2. Biogas Technology Resource Index Compiled by Ms. V. Vijayalekshmy. May 1985. 125p.

   The Resource Index provides a listing of over 1500 English language articles and other information materials on biogas technology. Includes an author index.

3. Photovoltaics Bibliography 1984 - 85. June 1985. 46p.

   The bibliography includes nearly 700 reports and other publications on photovoltaics, brought out by the Solar Energy Research Institute, Jet Propulsion Laboratory, and Sandia National Laboratory of the U.S.A.

B. Directories

4. Directory of Energy Environment Interests Groups in India June 1985. 40p.

   Includes information on the subject interests and energy and environment related activities of about 265 institutions in India. These institutions include the concerned Departments of the Central and State Governments, research institutions and voluntary agencies involved in the study of energy-environment interface.

C. Reviews and Summaries

5. Photochemical Conversion and Storage of Solar Energy : Summary of State-of-the-Art Presentations. August 1985. 22p Contains summaries of the invited lectures given at the Fifth International Conference on Photochemical Conversion and Storage of Solar Energy held at Osaka, during August 26-31, 1984. In addition, a brief survey of the state-of-the-art of photochemical conversion as manifested in the papers presented and the resultant discussions has also been included.

6. Recent Developments in Attempts for Chemical storage of Solar Energy : Report on the Fifth International Conference on Photochemical Conversion and storage of Solar Energy, Osaka, August 26-31, 1984 by Balu Venkatraman, Tata Institute of Fundamental Research Bombay, India. 82p.

   Presents an appraisal of the Fifth International Symposium on Photochemical Conversion held at Osaka. A review of the progress made and various approaches to future research in the areas of photoelectrochemistry, photocatalysis, organised molecular assemblies and unimolecular storage has been presented.

7. Photovoltaics : Recent achievements. Sept. 1985. 24p. Gives a state-of-the-art study of the U.S. Photovoltaics Programme and the significant developments made under it. Detailed account of the technological advances in the areas of materials research, collector research, systems research as also support activities like PV measurement techniques, characterisation and analysis has been provided.

D. Information Packages

8. Cookstove Technology : An Information Package Comp. by G. Ajith Kumar, Dec. 1985.

   An updated information package providing information on the state-of-the-art of cookstove technology and cookstove promotion programmes. Besides an annotated bibliography of cookstove literature, and information on international and national organisations involved in cookstoves research and promotion have also been included.

E. Documentation Bulletin

9. Energy Digest (ED) : A monthly summary of recent scientific and technical advances in the energy field. The ' Digest ' also highlights selected energy publications that may prove useful reading to energy manages, researchers and other serious students of energy and related technologies.

10. Indian Energy Abstracts (IEA) : A quarterly publication which provides abstracting coverage of scientific and technical reports, journal articles, conference papers and proceedings etc. References to the literature published prior to 1982 are included in a companion volume " Indian Energy Index : Non Conventional Energy Literature " published in May 1985.

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